Farm Dairy Effluent (FDE) Design Code of Practice

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 guide designers through the process of developing a farm dairy effluent (FDE) system, from the initial site investigation through to commissioning of the final system. It provides a general design approach, including lists of things that must be taken into consideration.

It is expected that designers will follow the general design process outlined here, but many will have their own specific procedures. This document should be used primarily to ensure that all of the main design aspects have been considered.

This document is intended to be used in conjunction with *FDE Design Standards* (2013). The design standards provide specific performance target values that must be achieved by all FDE systems.

Audience

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

Because of the diverse range of skills necessary to successfully develop an FDE system, it is not intended that any one person see the process through from start to finish. It is expected that different people, with different skills, will be involved at various stages.

This document is not for designers of storage ponds. It provides guidance on sizing and siting storages, but detailed design is complex enough to require its own set of guidelines.

Background

Rapid development has taken place recently in the New Zealand dairy industry, and DairyNZ has reported a lack of understanding of the fundamental design process by designers and suppliers of FDE systems. This lack of understanding 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 the design processes required to develop FDE systems that allow 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. It recognises the need for designers to interpret the guidelines according to individual requirements, provided any decisions comply with all regulatory requirements, existing industry standards, and the principles of preserving natural resources.

THE FDE SYSTEM DEVELOPMENT PROCESS

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 to 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; and
- To comply with all regulatory requirements, including consent conditions

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

2 PROCESS OVERVIEW

The process for developing an FDE system can be divided into the following key stages:

a) Gathering Information
b) Deciding Performance Parameters
c) System Design
d) Implementation

See Figure 1 for a graphical representation of this process.

Because of the diverse range of skills necessary to successfully develop an FDE system, it is not intended that any one person see the process through from start to finish. It is expected that different people, with different skills, will be involved at various stages.

Ideally, the design of the FDE system will be integrated with the design of other related farm infrastructure. For example, some aspects of the dairy shed design may be interconnected with the design of the FDE system.

Gathering Information

In the first stage, site specific information (e.g. farm plans, soil type, rainfall, animal numbers) is collected and the needs of the purchaser are determined.

Deciding Performance Parameters

In the second stage, the level of performance of the future system is determined. Design specifications are prepared, listing things that the final system must be able to achieve (e.g. application depth, application intensity, required storage volume) so that all regulatory requirements and the needs of the purchaser can be met.

System Design

In the third stage, components are selected that will perform in a way that meets the design specifications. System specifications are prepared describing in detail what the final system will comprise of and what it will be capable of achieving. Attention should be given to making the system easy for the farmer to use and an indication of how much time will be needed to operate and maintain the system on a daily basis should be given to the purchaser, before a decision on the system is signed off.

Implementation

In the fourth stage, the system is constructed and tested to ensure that it operates according to the system specifications. Instruction and training, including ongoing monitoring and maintenance requirements, are provided for the system operators.

Each of the four design stages is described in more detail in Sections 3-6.

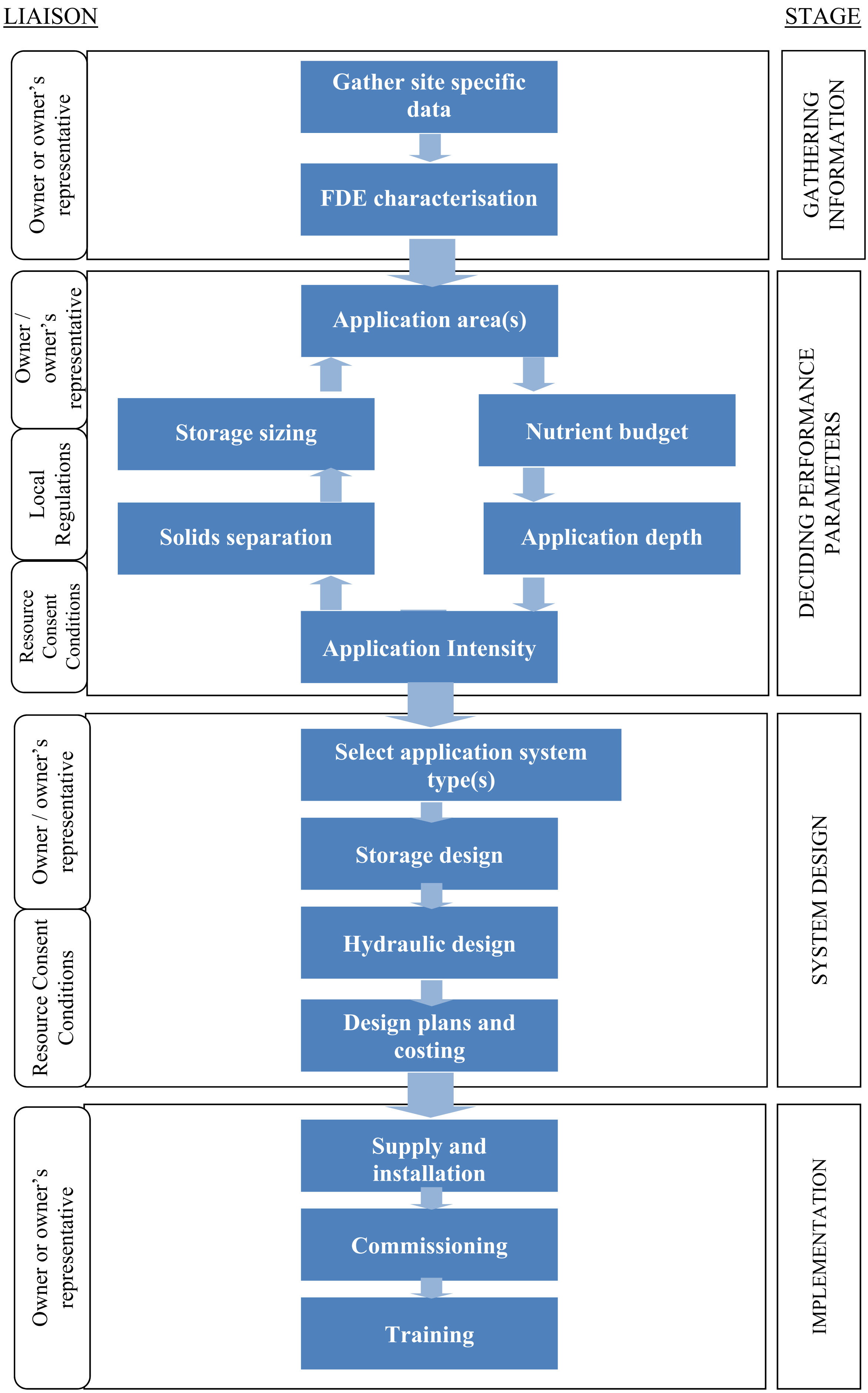

Figure 1: Process overview

3 GATHERING INFORMATION

The first stage in the development of a farm dairy effluent (FDE) system is to gather the necessary site-specific information needed to complete a design. A list of information to be discussed and obtained prior to proceeding with the design of a FDE system is listed in Table 1. These items are discussed in further detail in Sections 3.1-3.6.

Designers may obtain the necessary site specific information from a number of sources, including discussions with the purchaser, on-site measurements or samples, local councils, weather stations, or soil maps. The best known information sources must always be used.

A site visit checklist is provided in Appendix A to help with this process.

Table 1: Items to be discussed during the property visit

Item	Description
Site Layout	
Map	Obtain a copy of the property map, including all current infrastructure and land features, and any planned infrastructure.
Topography	Identify land features that may affect the design of the FDE system, including land slope, gullies, surface water bodies, flood risks, etc.
Design Area	Identify the potential areas for dairy sheds, storage locations, and for land application.
Fencing	Identify potential fencing arrangements, and how it will affect FDE land application equipment.
Shelter	Identify the natural or artificial wind breaks that are present or will be required.
Land Restrictions	Identify protected areas or covenants on titles, and the location of any sensitive areas.
Energy Source	If power is required, locate the nearest supply and identify its limitations.
Water Supply	Determine if there is a suitable water supply available for the washdown system.
Vandalism	Identify any potential for vandalism.
FDE Characteristics	
Nutrient Concentration	Determine the N, P, and K concentration likely to be in the FDE.
FDE Production Rate	Determine how much FDE will be produced each day, month, and year.
Solids Content	Determine the percentage and particle size distribution of solids in the FDE

Item	Description
Soils Information	
Soil Type	Identify the types and locations of the soils on the property.
Profile Available Water (PAW)	Determine the depth of water the soil can hold that is available to plants.
Infiltration Rate	Determine the speed at which the soil absorbs water. This may be affected by other soil or landscape features such as pans, drains, soil compaction, or ground slope.
Drainage	Identify any areas with poor or enhanced drainage. This may include natural or artificial soil drainage.
Climate Information	
Rainfall	Obtain rainfall records for the property, or from the nearest weather station.
Evapotranspiration	Determine typical plant water demand for the property.
Wind	Determine the prevailing wind directions for the property.
Farm Management Information	
Animal Numbers	Determine the number of cows milked in the dairy shed throughout the season – determine average and peak.
Milking Schedule	Determine the milking schedule, i.e., the number of milkings per day, or seasonal milking schedule.
Wash-water Use	For existing systems, determine the type of washdown system and its water use rate.
Labour	Determine the skill level of the labour available to operate the system.
Future Flexibility	Identify the likelihood and timing of future changes, e.g., an increase in stocking rate.
Process Control	Identify the purchaser's preferences for automated checks and controls.
Delivery	Determine the date by which the system is required to be operational.
Health & Safety	Identify any health and safety issues pertinent to the site.
Other	Identify any other issues relevant to the purchaser.
Regulatory Requirements	
Resource Consents	Check that all necessary resource consents have been obtained. Determine if other resource consents will affect the FDE system.
Local Requirements	Be aware that there may be local regulatory requirements regarding the storage or land application of FDE.

3.1 Site Layout

Information about the layout of the farm is necessary for siting infrastructure (e.g. storage, pipelines) and land application areas. Information gathered prior to the design of a FDE system can help identify any site restrictions or potential logistical limitations (e.g. topography, proximity to roads and neighbours).

Ideally, the design of the FDE system will be integrated with the design of other related farm infrastructure. For example, some aspects of the dairy shed design may be affected by the design of the FDE system.

Designers should obtain site layout information from the purchaser, and verify the key features during a farm visit.

3.2 FDE Characterisation

The characteristics of the FDE will have an impact on the design of a system intended to collect, store, and apply it to land. The physical and chemical properties of FDE are highly variable, and farm-specific information must be obtained wherever possible.

If solids separation is to be used, the characteristics of both the liquid and solid components of the FDE must be determined.

What is Included in FDE

FDE will comprise of all the animal excreta deposited in contained areas, as well as any other material coming into contact with it, including wash-water. An assessment of the FDE characteristics must include all material from:

- inside the milk shed
- any stand-off areas
- feed pads
- animal housing areas
- underpasses
- milk storage area(s)
- milk vat area, and
- all other sealed areas within 45 metres of the dairy shed where animals are contained.

Important Characteristics

The following characteristics of the FDE must be tested or accurately estimated prior to starting the design process:

- Nutrient Content
  Include:
    - Total Nitrogen (TN)
    - Total Phosphorous (P)
    - Total Potassium (K)
- Quantity
  The total volume of FDE produced per milking event, per day, and per season
- Total Solids Content (TS)

If solids separation is to be used, the characteristics of both the liquid and solid components of the FDE must be determined.

All samples being analysed for nutrient or solids content must be analysed by a laboratory accredited for that method of analysis by International Accreditation New Zealand (IANZ), or an equivalent authority. Sample collection bottles and sampling procedures can often be obtained from a local accredited laboratory.

Variability

Characteristics of FDE will vary with time and location because of variations in:

- feed content
- milk production rate
- number of times milked per day
- animal age
- animal weight
- lactation cycle, and
- water dilution.

Expected variation for a given farm must be measured or estimated and considered throughout the rest of the design process (e.g. variation in volume due to changes in milking schedule throughout the year).

Methods of Characterisation: Sampling

Where appropriate, an FDE designer may determine the properties of FDE by sampling. Sampling is only appropriate where the expected variability can be captured. This will require several samples, taken over the course of a season.

When determining FDE properties relevant to conveyance and storage, take samples at a point "as close to the cow" as possible. For determining FDE properties relevant to land application, take samples at a point "as close to the paddock" as possible.

Samples taken from an existing storage facility are also adequate if the storage has been fully agitated.

If a system is being upgraded or changed in any way (e.g. upgrading the wash-down system, changing pond size, adding solids separation), it is important to note that the characteristics of FDE "close to the paddock" are likely to change. Testing FDE from the old system may not always provide an accurate depiction of FDE after the upgrade.

Methods of Characterisation: Calculation

Where appropriate, an FDE designer may determine the properties of FDE by theoretical calculation. This will be the method of choice when relevant measurements are not available (as in the case of a new conversion).

When calculating the characteristics of FDE, all assumptions must be stated clearly to the purchaser. The main assumptions that must be made include:

- Volume of manure plus urine (undiluted FDE) produced
- Solids content of the undiluted FDE
- Nutrients produced (kg of N, P, K)
- Percentage of daily manure plus urine that is deposited in contained areas
- Volume of wash-water used, and
- Expected variability

Table 2 gives typically reported values for some of these parameters.

Table 2: Estimated daily manure plus urine (undiluted)

Parameters	**Manure + Urine (V_{M+U}) [(a)] per cow per 24 hours (reported range in parentheses)**
Volume (ℓ/cow/day) [V_{M+U}]	70 (55-85)
Solids (% by weight)	10 % (8-12)
N (kg/cow/day)	0.3 (0.15-0.45)
P (kg/cow/day)	0.03 (0.02-0.08)
K (kg/cow/day)	0.3 (0.06-0.37)

All values based on mid-range values from the most relevant publications in a literature review.
[(a)] Total produced per animal over one 24 hour period.

Equations 1-5 provide guidance for calculating other important design parameters. In addition, there are several analytical tools available to FDE designers to help calculate expected FDE characteristics. For example, the Overseer® software programme is available free of charge from AgResearch Ltd. (www.overseer.org.nz).

The total volume of FDE produced (per cow) each day can be estimated by:

$$V_{fde} = (V_{M+U} * T_{pad} / 24) + V_{wash} + V_{other} \quad (1)$$

Where:

V_{fde} = volume of diluted FDE captured per animal per day (ℓ/cow/day)
V_{M+U} = volume of manure + urine produced per animal per day (ℓ/cow/day)
T_{pad} = number of hours each day that animals spend on collection areas
V_{wash} = volume of wash-water used per animal per day (ℓ/cow/day)
V_{other} = volume of any other material mixed with FDE (e.g. bedding)

The solids content of the diluted FDE can be estimated by:

$$P_d = P_o * (V_{fde} - V_{wash}) / V_{fde} \quad (2)$$

Where:

P_d = solids content of the diluted FDE (%)
P_o = original solids content of the undiluted FDE (%)
V_{fde} = volume of diluted FDE captured per animal per day (ℓ/cow/day)
V_{wash} = volume of wash-water used per animal per day (ℓ/cow/day)

Total nutrients captured per animal per day may be estimated by:

$$N = N_{M+U} * T_{pad} / 24 \quad (3)$$

Where:

N = nutrient captured per animal per day (kg/cow/day of N, P, or K)
N_{M+U} = nutrient produced per animal per day (kg/cow/day of N, P, or K)
T_{pad} = number of hours each day that animals spend on collection areas

Example Calculation:

Consider a dairy farm whose cows are expected to excrete 65-75 ℓ of manure plus urine (undiluted FDE) each day, and will spend 1.0-1.5 hours each day on a concrete pad. Further, the single washdown is expected to use 40-50 ℓ of wash-water per cow each day. The expected range in daily FDE production can be estimated using Equation 1:

$$V_{fde} = (V_{M+U} * T_{pad} / 24) + V_{wash} + V_{other}$$

$$V_{fde\text{-}max} = (75\ \ell/day * 1.5\ hrs / 24\ hrs) + 50\ \ell/day + 0 = 55\ \ell/day$$

$$V_{fde\text{-}min} = (65\ \ell/day * 1.0\ hrs / 24\ hrs) + 40\ \ell/day + 0 = 43\ \ell/day$$

The FDE system should therefore be designed to handle an expected FDE loading of 43-55 ℓ/cow/day. Further investigation will need to be done to determine how this range is distributed through the season.

The nutrient concentration in the diluted FDE may be estimated for each individual nutrient by:

$$[N] = [N]_o * (V_{fde} - V_{wash}) / V_{fde} \quad (4)$$

Where:

$[N]$ = nutrient concentration in the diluted FDE (%)
$[N]_o$ = nutrient concentration in the undiluted FDE (%)
V_{fde} = volume of diluted FDE captured per animal per day (ℓ/cow/day)
V_{wash} = volume of wash-water used per animal per day (ℓ/cow/day)

or

$$[N] = 10^6 * N / V_{fde} \quad (5)$$

Where:

$[N]$ = nutrient concentration in diluted FDE (mg/ℓ or g/m^3 of N, P, or K)
N = nutrient captured per animal per day (kg/cow/day of N, P, or K)
V_{fde} = volume of diluted FDE captured per animal per day (ℓ/cow/day)

Example Calculation:

Consider the dairy farm in the previous example. Assuming that each cow is expected to produce 0.25-0.35 kg of Nitrogen each day, the Nitrogen concentration in the diluted FDE may be calculated by combining Equations 3 and 5:

$$[N] = (10^6 * N_{M+U} * T_{pad}) / (V_{fde} * 24)$$

$$[N]_{max} = (10^6 * 0.35 \text{ kg N/day} * 1.0 \text{ hrs}) / (43 \text{ ℓ/day} * 24 \text{ hrs}) = 340 \text{ mg N/ℓ}$$

$$[N]_{min} = (10^6 * 0.25 \text{ kg N/day} * 1.5 \text{ hrs}) / (55 \text{ ℓ/day} * 24 \text{ hrs}) = 284 \text{ mg N/ℓ}$$

The system design must therefore be based on an expected Nitrogen concentration of 284-340 mg/ℓ.

3.3 Soil and Landscape Features

Information must be obtained about the site's soils and landscape to ensure that the FDE land application system is designed to match on-site conditions. Knowledge of soil and landscape features is necessary for calculating an appropriate depth, intensity, and area for land application.

To determine soil properties:

- dig test pits and/or measure the necessary parameters, or
- refer to soil maps (e.g. from the Regional Council, or S-Map from Landcare Research).

Designers must always verify soil properties on-site, regardless of their method of determination.

Soil and Landscape Classifications

Soil and landscape features may be categorised, according to their relevance to FDE management, into one of the following classifications:

A. Artificial Drainage or Coarse Soil Structure

B. Impeded Drainage or Low Infiltration Rate

C. Sloping Land (>7° slope) and "Hump and Hollow" Drained Land

D. Well Drained Flat Land (<7° slope)

E. Other Well Drained but Very Stony Flat Land (<7° slope)

This classification system will be used to determine an appropriate FDE application depth and storage size in Sections 4.3 and 4.6.

Soil Water Holding Capabilities

It is important to know the volume of water that a particular soil can hold. This information is used to determine how much FDE may be applied without exceeding the capacity of the soil to take it in.

There are many different ways to describe a soil's moisture holding characteristics. The most important description relevant to the land application of FDE is Profile Available Water (PAW). A soil's PAW value describes the maximum amount of water that can be held in the soil that is extractable by plants (i.e. available water).

If soil and landscape class A, B, or C (see *Soil and Landscape Classifications*, above) are present in the FDE application area, then determine PAW for each of the soil types. PAW will later be used, in conjunction with climate data, to calculate the expected soil water deficit throughout the year, as required by Table 5.

Local PAW values may be obtained from a number of sources, including soil maps, Regional Councils, and Landcare Research. It may also be calculated by verifying the soil layers present (i.e. by digging test pits) and multiplying the depth of each layer by the estimated percentage volume of soil water in each layer (see Table 3).

If soil and landscape class D or E (see *Soil and Landscape Classifications*, above) is present in the FDE application area, then calculate PAW_{30}. PAW_{30} is the amount of available water in the upper 30 cm of the soil. This may be calculated by determining the soil types present in the upper 30 cm (i.e. by digging test pits) and multiplying the depth of each layer by the estimated percentage volume of soil water in each layer (see Table 3).

Table 3: Estimated soil water holding characteristics

Soil class	**Volumetric Soil Water Content (%)**	**PAW (mm) [b]**
Clay loam	17-21	150-190
Silt loam (no stones or gravel)	12-17	110-150
Silt loam (< 30% stones by volume) [a]	8-10	75-90
Sandy loam	7-13	60-120
Sand	5-7	45-60

[a] For soil with ≥ 30% stones, scale the given values for silt loam (no stones or gravel) relative to the volume of stones.
[b] Assumes a soil profile depth of 90 cm.

Example Calculation:

Soil test pits in the proposed FDE application area have shown an average soil profile as follows:

- *Top 30 cm – silt loam, no stones*
- *Next 60 cm – very stony silt loam (50% stones)*

PAW in this profile can be estimated by multiplying the depth of each layer by its expected volumetric soil water content from Table 3. The amount of available water in the surface 30 cm of soil can be estimated as:

*30 cm/90 cm * 130 mm = **43 mm*** *(this is also PAW_{30})*

To calculate the volumetric soil water content in the remaining 60 cm of soil:

*Water Content (50% stones) = Water Content (no stones) * 50%*

The amount of available water in the remaining 60 cm of soil can be estimated as:

*60 cm/90 cm * 130 mm * 0.50 = **43 mm***

*Therefore, the total amount of available water held in the entire 90 cm soil profile (PAW) is approximately **86 mm**.*

Soil Infiltration Rate

Soil infiltration rate must be deter each soil type encountered in the proposed land application area(s). In the ab te specific measurements, Figure 2, Table 4, and Table 6 may be used to esti nfiltration rate based on soil type.

The curves presented in Figure 2 ctual soil infiltration rate curves, as they have been modified to take into he application intensity of applied water (INZ, 2007).

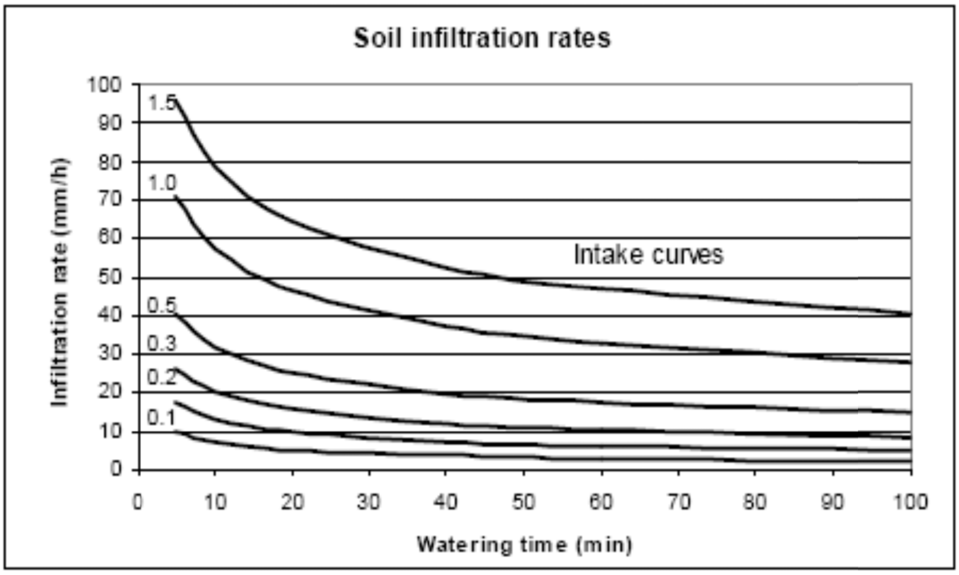

Figure 2: Soil infiltration rates ac watering time (source: INZ, 2007)

Table 4: Approximate soil intake urce: INZ, 2007)

Soil class	A intake curve number
Tight clay	0.1
Clay/clay loam	0.1-0.2
Silt loam	0.2-0.3
Sandy, stony silt loam	0.3-0.5
Sandy loam and fine sand	0.5-1.0
Sand	1.0-1.5
Coarse sand	1.5

3.4 Climate Information

Obtain information about the local climate (i.e. rainfall, evapotranspiration, wind direction statistics) to ensure that the FDE system is designed to match on-site conditions. Knowledge of the climate parameters listed in Table 1 is necessary for calculating an appropriate storage size and application depth.

As discussed further in Section 4.6, climate data sets will be required for determining statistics regarding:

- the size and frequency of different sized precipitation events
- air and soil temperature, and
- expected soil moisture.

Climate information may be obtained from:

- a local weather station or on-farm weather recorder
- NIWA's Virtual Climate Station Network
- climate maps of the region, e.g., maps from the regional council, or
- local expert advice, i.e., from someone who has specific knowledge about the climate in the area.

Always use the most accurate, relevant sources available.

3.5 Farm Management Information

It is important that the FDE system fits into the management of the farm as a whole. Ensure that farm management needs are identified prior to designing a FDE system. See Table 1 for some examples of things that should be considered.

A design must consider the purchaser's current needs, and any additional needs into the foreseeable future (e.g. are stocking rates planned to change?).

A design must accommodate the balance of capital investment and on-going operational costs required by the purchaser.

A design must also consider the logistical needs of the purchaser (e.g. when does the system need to be operational, and what level of labour skill is required?).

3.6 Regulatory Requirements

Check with relevant local, regional, and national rules to ensure that:

- the planned FDE facilities are classified as a permitted activity, or
- necessary resource consents have been obtained for the FDE system, and
- there are no other regulatory requirements (including local regulations or resource consent conditions) that may affect the FDE system.

4 DECIDING PERFORMANCE PARAMETERS

The second stage in developing a farm dairy effluent (FDE) system is to determine the level of performance the future system must achieve if local regulations, consent conditions, and the needs of the purchaser are to be met.

Determination of many of the parameters described in this section is interdependent on one or more other parameters. All parameters are site specific. As such, developing a complete set of design specifications is often an iterative process, involving continual cross-checking of input information, calculated values, resource consent requirements, and farm management requirements.

4.1 Sizing the Land Application Area(s)

Calculate the minimum area of land to be used for the application of FDE using:

- Local regulatory requirements for nutrient loading (i.e. kg N/ha), and
- A nutrient budget
  A nutrient budget will define a minimum application area that is based on using nutrients most effectively.

Of the two results, use the one requiring the largest area as a design specification.

The following equation may be used to calculate the required FDE land application area:

$$A = ([LN] * V_{ann}) / (1{,}000 * ML) \quad (6)$$

where:

A = minimum required FDE land application area (ha)
[LN] = concentration of limiting nutrient in FDE (mg/ℓ, g/m^3)
V_{ann} = total FDE produced on whole farm per year (m^3/yr)
ML = maximum loading criteria for limiting nutrient (kg/ha/yr)
(i.e. the regulatory limit, or maximum effective loading calculated from a nutrient budget)

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

Limiting Nutrient

The limiting nutrient, [LN], is 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.

Maximum Loading Criteria (ML)

The maximum loading criteria is the most stringent of:

- The local regulatory limit for nutrient loading, or
- The maximum amount of nutrient that may be applied and beneficially used by the plants, based on a nutrient budget.

When sizing the land application area, the maximum loading criteria for nitrogen, phosphorus, and potassium must be calculated, and the most limiting of these (i.e. lowest kg/ha/yr) should be used in the design.

It is also prudent to consider the health effects on cows from high potassium loading.

4.2 Nutrient Budget

A nutrient budget must be prepared for the area where FDE is to be applied. This is necessary for determining many of the design specifications.

The following must be taken into account when completing a nutrient budget:

- All farm nutrient inputs, including FDE, fertiliser, N-fixing plants (legumes), animal deposits, and any other supplements.
- All farm nutrient removal processes, including volatilisation, leaching, denitrification, and plant requirements.
- Health standards to be met, i.e., timing of irrigation with respect to stock grazing, or observing minimum separation distance from dwellings, bounding roads, and surface water bodies.

Nitrogen, phosphorus, potassium, and any other elements of local concern must be included in the nutrient budget.

A design must state which of the above considerations have been included as part of the design process. If any of the above items are not included in the nutrient budget, the designer must explain why it was not necessary to include them.

If solids separation is used, both the liquid and solid components of FDE must be considered separately in the nutrient budget. This will require separate analysis of the liquid and solid components of the FDE.

Nutrient budgets are often already completed by the farmer (or consultant) on a regular basis. This budget is often adequate. In addition, there are several analytical tools available to FDE designers who wish to complete an independent nutrient budget. For example, the Overseer® software programme is available free of charge from AgResearch Ltd (www.overseer.org.nz).

4.3 Land Application Depth

Selection of an appropriate land application depth depends primarily on the:

- nutrient content of the FDE
- nutrient status of the soil
- nutrient requirements of pasture or crop
- landscape features
- water holding capacity of the soil, and
- soil water deficit at the time of application.

The FDE system must be capable of applying an appropriate range of depths to:

- keep the applied FDE in the root zone of the plants
- avoid exceeding the nutrient requirements of the plants, and
- comply with resource consent conditions.

If solids separation is used, both the liquid and solid components of FDE must be considered separately when calculating application depth. This will require separate analysis of the liquid and solid components of the FDE.

Keeping FDE in the Root Zone

To keep the applied FDE in the root zone of the plants, it is recommended that the design application depth be selected to meet the requirements in Table 5.

Table 5: 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.

For many soil and landscape types, determination of application depth will be linked to storage size and soil moisture characteristics. A properly sized storage will allow for a soil moisture deficit to occur, so that a reasonable depth of FDE may be applied without causing problems. See Section 4.6 for more information on how to properly size the storage.

Avoiding Excessive Nutrient Application

It is recommended that the system be designed so that no more than 50% of the annual nutrient demand for a given area is applied during each application event.

Spreading the yearly nutrient target for a given area over several applications increases the likelihood of retaining the nutrients in the plant root zone, and increases the availability of nutrients throughout the year.

Most current regulations refer to nitrogen loading (i.e. kg N/ha/yr). But, the design application depth should be calculated in terms of the limiting nutrient, which may be something other than nitrogen.

Regulatory Considerations

Local regulatory requirements, including resource consent conditions, always take precedence if they are more stringent than calculated values.

4.4 Maximum Application Intensity

The land application system must be designed so that the application intensity of the system does not exceed the infiltration rate of the soil.

In preparing a design specification, the soils information should be used to:

- determine the expected infiltration rate of each soil in the application area (see Section 3.3)
- adjust it for any site-specific conditions (e.g. high solids content in the FDE, see below), and
- identify potential problem areas where infiltration rate is likely to be especially low (e.g. compacted areas).

The designer must specify an application intensity that the final FDE land application system must not exceed.

Adjusting Infiltration Rate – Solids in FDE

Solids in FDE have the potential to reduce a soil's infiltration rate by physically blocking the surface pores. This effect is most severe (largest % reduction) when applying FDE (containing fine solids) to coarse grained soils, because the naturally large pores (which normally have a high infiltration rate) become blocked with finer material.

Table 6 presents approximate coefficients that may be used to adjust the soil infiltration rate. Use this table to account for FDE solids being applied to the surface.

Table 6: Infiltration rate adjustment coefficients for solids in FDE (source: Table 11-3, USDA, 1997)

	Percent solids (by weight)						
	0.5%	**1%**	**2%**	**3%**	**5%**	**7%**	**10%**
Soil texture	***Infiltration rate adjustment coefficients***						
Sand	0.88	0.55	0.31	0.22	0.13	0.10	0.07
Loamy sand	0.70	0.54	0.37	0.28	0.19	0.14	0.10
Sandy loam	0.87	0.77	0.63	0.53	0.40	0.32	0.25
Loam	0.97	0.93	0.88	0.83	0.74	0.67	0.59
Silt loam	0.98	0.95	0.91	0.87	0.81	0.75	0.68
Sandy clay loam	0.99	0.97	0.95	0.92	0.87	0.83	0.78
Clay loam	0.99	0.99	0.98	0.97	0.94	0.92	0.89
Silty clay loam	1.00	1.00	0.99	0.99	0.98	0.97	0.96
Sandy clay	1.00	1.00	1.00	1.00	0.99	0.99	0.99
Silty clay	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Clay	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Example Calculation:

For a silt loam subjected to a 30 minute watering time, an infiltration rate of approximately 14 mm/hr (from Figure 2 and Table 4) may be expected. If irrigating with clean water (no solids), the irrigation system must be designed for an application intensity of ≤14 mm/hr.

However, if applying a FDE with 5% solids content, the design application intensity will need to be adjusted by the coefficient from Table 6:

*14 mm/hr * 0.81 =* ***11 mm/hr***

Therefore, the irrigation system must be designed for an application intensity of ≤11 mm/hr.

4.5 Solids Separation

The choice to separate solids will affect many of the other design parameters, e.g., the nutrient budget, application depth, storage requirement. Therefore, the decision to separate solids should be made as early as possible.

Solids separation may not be necessary if:

- the FDE is already of an easily workable consistency (i.e., it is very dilute)
- an appropriate land application system is available that can handle the solids or
- the purchaser has a preference for non-separated systems.

Figure 3 gives an indication of the relationship between FDE solids content, and common conveyance and land application methods. This may be used as a guide as to whether or not solids separation is required.

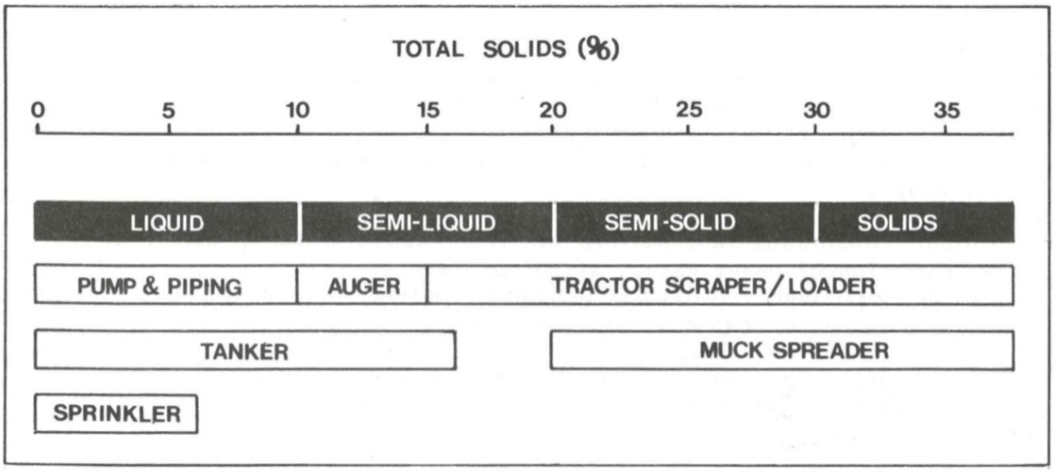

Figure 3: Guide to conveyance and application methods appropriate to FDE (source: Table 3.10, NZAEI, 1984)

Particle Size

If solids separation is to be used, the size of particles to be removed from the FDE should be specified.

4.6 Storage Sizing

In New Zealand, liquid FDE storage is generally designed to hold the FDE until it can be applied to land. Storage volume must be sufficient so that the system manager is able to apply FDE to land:

- at a time that allows uptake by the plant, and
- when it is least likely to cause environmental contamination.

Storage volume must be sufficient to avoid application to saturated or frozen soils which increase the potential for leaching and surface runoff.

Liquid Storage

The required storage volume must be the greater of:

A: Regulatory requirements, OR

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

- FDE Volume
  This is the accumulated volume of FDE that will be added to the storage during the storage period (see Section 3.2, *What is included in FDE*).
- Storage Period
  This is the length of time that FDE must be 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) (see Table 5).
- 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 runoff from rainfall onto all areas that drain into the storage during the storage period.
- Contingency for Large Storm Events
- 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.
- Freeboard Allowance
- 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. A minimum allowance of 3 days is recommended, but this will depend on location and access to necessary services.
- Potential for Future Increase in Stocking Rate

There are several analytical tools available to FDE designers to help with pond sizing. For example, the Massey University/Horizons Regional Council "Dairy Effluent Storage Calculator", uses farm specific inputs and 30 year climate data to determine storage requirements.

Solids storage

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, and the potential for periods of high soil moisture, frozen ground, or periods of limited staff availability.
- 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.

5 SYSTEM DESIGN

The third stage in developing a farm dairy effluent (FDE) system is to select components and create detailed plans describing how the system will achieve the design specifications. System specifications are also prepared, listing what the final system will comprise of, and what it will be capable of achieving.

5.1 Land Application System Selection

A land application system must be selected that meets or exceeds all of the requirements of the design specifications. Application depth and application intensity are the key specifications likely to drive the selection process. However, the system must also be suitable for the farming enterprise type, and meet any other client needs.

Special emphasis should be given to providing a system that is capable of a low application intensity and a low application depth where soil and landscape features dictate this as beneficial.

Because of the nutrient content of FDE, it is especially important for FDE irrigation to be applied with high uniformity. Highly uniform application maximises the nutrient benefit to pasture and avoids potential adverse effects on water quality.

Special emphasis should also be given to selecting components that are able to handle the solids content of FDE without blockages.

Note the section on *Special Considerations for the Application of Separated Solids*.

Adjusting Application Depth for Uniformity

The design specification for application depth (Section 4.3) needs to be adjusted for the application uniformity of the selected system. The application depth, adjusted for uniformity, must still be less than the depth listed in the design specification. Make this adjustment prior to preparing the final system specification.

An upper quartile distribution uniformity (DU_{uq}) is recommended as a measure of FDE land application uniformity. DU_{uq} is a measure of uniformity that focuses on the one quarter of the application area that receives the highest applied depth (D_{uq} – see Figure 4). Therefore, minimising DU_{uq} means minimising over-application of FDE while maximising the mean depth that can safely be applied.

DU_{uq} is calculated by:

$$DU_{uq} = D_{uq} / D_{avg} \qquad (7)$$

where:

DU_{uq} = Upper quartile distribution uniformity

D_{uq} = Mean depth of FDE applied to the one-quarter of the area receiving the greatest depth

D_{avg} = Mean depth of FDE applied to the whole area

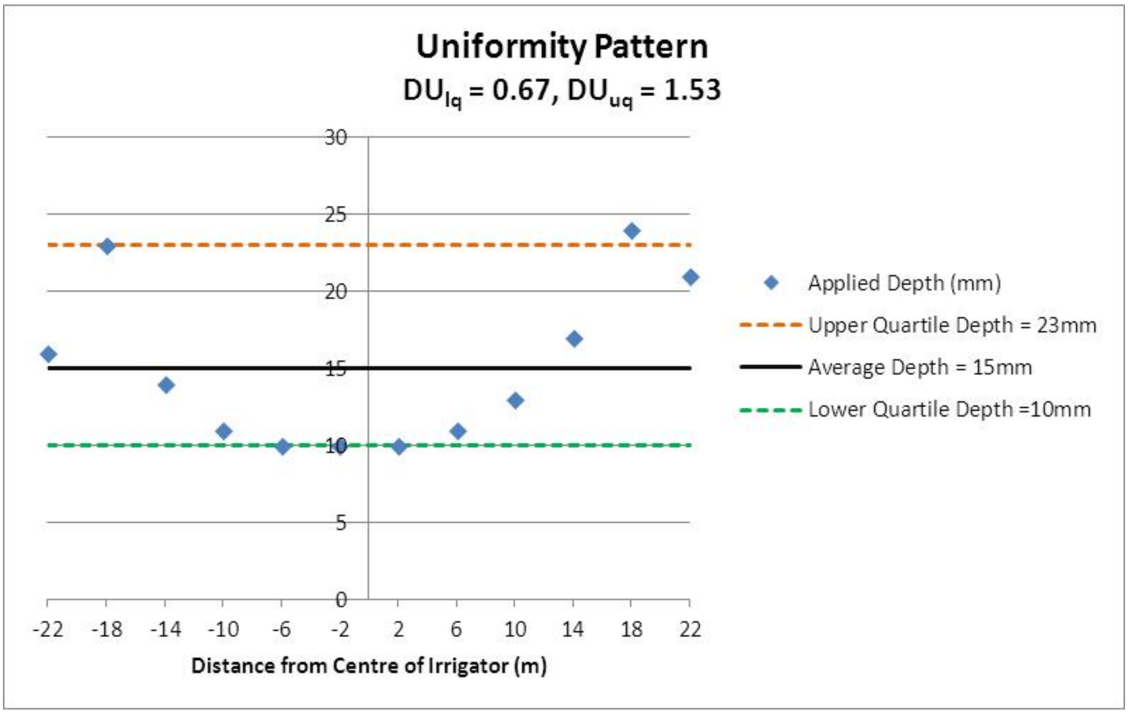

Figure 4: Spatial distribution of applied depth under an example FDE irrigator.

Use the following formula to calculate the target application depth that must be included in the system specification:

$$D_{target} = D_{spec} / DU_{uq} \tag{8}$$

where:

D_{target} = Target application depth to list in the system specification
D_{spec} = The application depth calculated in Section 4.3
DU_{uq} = Upper quartile distribution uniformity

If DU_{uq} information is not available, a design may use the low quartile equivalent, DU_{lq} as a substitute. DU_{lq} focuses on the quarter of the area that receives the least applied depth. If the distribution pattern is normally distributed, DU_{lq} = 0.80 is equivalent to DU_{lq} = 1.25.

Example Calculation:

> *Assume the design specification indicates a maximum application depth of 15 mm, based on the factors discussed in Section 4.3. Further assume that the manufacturer of the applicator has specified a $DU_{uq} = 1.2$.*
>
> *The designer must specify a D_{target} that would result in a $D_{uq} \leq 15$ mm. The design depth, D_{target}, may be calculated using Equation 8:*
>
> $$D_{target} = D_{spec} / DU_{uq}$$
>
> $$D_{target} = 15mm / 1.2$$
>
> $$D_{target} = 12.5 \text{ mm}$$
>
> *This means that in order to ensure the application depth is ≤15 on most of the application area, the average application depth must be ≤ 12.5 mm.*

Adjusting Application Depth for Management Reasons

The design specification for application depth (see Section 4.3) needs to be adjusted to reflect farm management preferences and the physical capabilities of the chosen application method. Adjust this prior to preparing the final system specification.

Generally, the depth applied in any single event should be made as low as possible for the particular application method chosen. This will allow for:

- spreading the annual nutrient load for a given area over several applications
- increasing the likelihood of retaining the nutrients in the root zone of the plants, and
- maximising the benefit of nutrients present in FDE.

More flexibility built into the design allows for more flexibility in management practices. The extent to which the system manager can vary the depth of FDE applied will depend primarily on the irrigation system type. An adjustable application depth will also help account for estimation errors in previous steps, e.g., wash-water use or FDE concentration.

Application Intensity

The land application system must be designed so that the application intensity of the system does not exceed the infiltration rate of the soil. The maximum allowable application intensity should already have been calculated, and listed in the design specification (see Section 4.4).

The designer must specify a land application system capable of meeting the design specification. For most situations, it is not necessary to consider the instantaneous application intensity – maintaining an average application intensity below the design specification will be adequate. For sloping land (> 7°) or other areas identified as high risk, the instantaneous application intensity must be considered.

For most FDE irrigators, the average application intensity may be calculated by:

$$R_a = 3,600 * Q_{app} / A_{app} \quad (9)$$

where:

- R_a = Average application intensity (mm/hr)
- Q_{app} = Flow rate to the applicator (ℓ/s)
- A_{app} = Wetted area of the applicator (m^2) (this is calculated differently for different types of applicators, see below)

Equation 9 applies to most common irrigation types, including the following:

- Individual Sprinklers
  For individual FDE sprinklers, A_{app} is the total area wetted by the sprinkler, and Q_{app} is the flow rate to the sprinkler. This applies to all individual sprinklers, e.g. long laterals, or separate effluent sprinklers attached to pivot spans.
- Multi-Sprinkler Lines
  For stationary applicators with multiple sprinklers, A_{app} is the total area wetted by all of the sprinklers on the individual line, and Q_{app} is the flow rate to that line.
- Rotating Booms
  For a rotating boom irrigator, A_{app} is the area wetted by one full rotation of the boom, and Q_{app} is the flow rate to that machine.
- Gun Irrigators
  For gun irrigators, A_{app} is the area wetted by one swing of the gun across its operating arc, and Q_{app} is the flow rate to that machine. This applies to all gun irrigators, e.g., a travelling gun, or effluent gun attached to a centre-pivot.
- Travelling Boom or Linear Move
  For travelling linear system, A_{app} is the total area wetted by all of the sprinklers on all spans when the machine is stationary, and Q_{app} is the flow rate to the machine.
- Separate Systems Attached to Centre-Pivots
  For systems where a separate FDE applicator is attached to a centre-pivot, the application intensity is calculated as if the FDE applicator were operating as a separate unit, e.g., a stationary sprinkler, or a gun irrigator (as above).

Example Calculation:

Consider an impact sprinkler with a wetted diameter of 20 metres and a flow rate of 2 ℓ/s, operating on level, well drained land. The average application intensity may be calculated by Equation 9:

$$R_a = 3{,}600 * Q_{app} / A_{app}$$

$$R_a = 3{,}600 * 2\ \ell/s / (\pi * (10\ m)^2) = 23\ mm/hr$$

This sprinkler must only be used if the soil's infiltration rate is ≥ 23 mm/hr.

Further, given a design application depth of 15 mm, this sprinkler could operate for approximately 39 minutes before exceeding the design application depth.

Example Calculation:

Consider a travelling rotating boom irrigator with a circular wetted diameter of 60 metres and a flow rate of 10 ℓ/s, operating on level, well drained land. The average application intensity may be calculated by Equation 9:

$$R_a = 3{,}600 * Q_{app} / A_{app}$$

$$R_a = 3{,}600 * 10\ \ell/s / (\pi * (30\ m)^2) = 13\ mm/hr$$

This irrigator must only be used if the soil's infiltration rate is ≥ 13 mm/hr.

For systems where FDE is injected into a centre-pivot, calculate the average application intensity, using the following equation:

$$R_a = 7{,}200 * (Q_{app} / r_e^2) * (r / W) \qquad (10)$$

where:

- R_a = Average application intensity (mm/hr)
- Q_{app} = Total flow rate to the irrigator, including FDE and water (ℓ/s)
- r_e = Total wetted length of the centre-pivot (m)
- r = Radial distance from pivot centre to the point under study (m)
- W = Wetted width (diameter) of nozzle pattern at *r* (m)

Example Calculation:

FDE is injected into a 500 metre long centre-pivot at a rate of 5 ℓ/s, and combined with irrigation water that is being pumped at 40 ℓ/s. The sprinklers used on the centre-pivot have a wetted diameter of 15 metres.

The average application intensity at 2/3rd of the full radius may be calculated by Equation 10:

$$R_a = 7{,}200 * (Q_{app} / r_e^2) * (r / W)$$

$$R_a = 7{,}200 * (45\ \ell/s\ / (500\ m)^2) * (333\ m / 15\ m) = 29\ mm/hr$$

The average application intensity at the full effective radius is calculated by Equation 10:

$$R_a = 7{,}200 * (45\ \ell/s\ / (500\ m)^2) * (500\ m / 15\ m) = 43\ mm/hr$$

Ideally, this system would only be used to apply FDE if the soil's infiltration rate is ≥ 43 mm/hr.

Careful consideration is necessary when designing for instantaneous application intensity. Peak intensity can be an order of magnitude greater than the average intensity for some land application systems. Even for centre-pivots, which generally experience a relatively low variation in intensity, peak application intensity is typically ≥25% higher than the average intensity.

Methods for calculating the instantaneous application intensity will be different for each type of applicator, and should ideally be directly measured or obtained from the manufacturer.

Application Intensity – Special Considerations

On some areas of the property, it may be difficult to maintain an application intensity less than the infiltration rate of the soil. These areas should ideally not be used for the land application of FDE. But, if soils with particularly low infiltration rates are to be encountered under some circumstances, designers must:

- identify when and where the application intensity is most likely to exceed the infiltration rate
- explain the consequences of it happening, and
- prescribe operational guidelines to avoid any adverse effects (i.e. describe the conditions under which it is not okay to operate the FDE system).

Travel Speed

If a travelling irrigator is used to apply FDE, an appropriate travel speed must be selected so that the design application depth is not exceeded.

The desired travel speed of the irrigator may be calculated by:

$$S_t = (3{,}600 * Q_{app} * W) / (A_{app} * D_{target}) \quad (11)$$

where:

- S_t = Specified travel speed of the irrigator (m/hr)
- Q_{app} = Flow rate to the applicator (ℓ/s)
- W = Width of wetted pattern, in the direction of travel (m)
- A_{app} = Wetted area of the applicator (m^2)
- D_{target} = Average application depth (mm)

or

$$S_t = R_a * W / D_{target} \quad (12)$$

where:

- S_t = Specified travel speed of the irrigator (m/hr)
- R_a = Average application intensity (mm/hr)
- W = Width of wetted pattern, in the direction of travel (m)
- D_{target} = Average application depth (mm)

Some machines have fixed speed increments (e.g. user selects from one of four pre-programmed speeds). In this instance, a set-point must be available on the specified machine that allows for an actual travel speed ≥ S_t.

Example Calculation:

Assuming a travelling rotating boom irrigator with a circular wetted diameter of 60 metres, and a flow rate of 10 ℓ/s, the application intensity was calculated in a previous example calculation to be 13 mm/hr. If the design application depth is 15 mm, then the required travel speed may be calculated by Equation 12:

$$S_t = R_a * W / D_{target}$$

$$S_t = 13 \text{ mm/hr} * 60 \text{ m} / 15 \text{ mm} = 52 \text{ m/hr}$$

Therefore, this irrigator would be required to travel ≥ 52 metres every hour in order to apply ≤ 15 mm.

Stream Impact Energy

The impact of FDE falling onto the soil may cause movement of soil particles or the breakdown of the soil into smaller particles, potentially resulting in a reduction of infiltration rate.

To minimise problems with soil breakdown and movement, it may be necessary to avoid using particular types of irrigation systems. Designers should:

- identify potential problems with stream impact energy
- select a system type to minimise or eliminate these problems, and
- make potential problems known to the purchaser of the system.

Special Considerations for the Application of Separated Solids

In New Zealand, the land application of separated solids (i.e. the fraction of FDE that is not applied through a pumped system) is not typically part of a FDE system specification. The spreading of separated solids is commonly carried out manually, as part of normal farm operations, sometimes by farm staff or a contractor.

However, if the land application of separated solids is to be included in a FDE system specification, it is recommended that it be treated similarly to a fertiliser because of its high nutrient content.

Systems used in the application of settled solids as a liquid, such as "pond pumping", must meet the standards specified in the accompanying *Farm Dairy Effluent Design Standards (2013)*.

5.2 Land Application Area(s)

Deciding the Final Size of Area(s)

The actual size of the application area(s) may be any area greater than or equal to the minimum required area listed in the design specification (see Section 4.1). The maximum size of the area will be limited by:

- the amount of available, suitable land, taking into account:
    - soil type(s)
    - ground slope
    - drainage
    - nearby surface water bodies
    - minimum separation distances to neighbouring dwellings, and
    - prevailing wind conditions.
- management factors, and
- capital and operating costs.

Location of the Land Application Area(s)

When locating potential land application area(s), the following must be considered:

- Topography, and suitability for irrigation
- Soil properties
- Presence of artificial drainage
- Minimum separation distances to sensitive areas, including surface water bodies and neighbouring dwellings
- Ease of access from FDE storage area(s)
- Prevailing wind direction
- Paddock layout
- Management factors
- Regulatory requirements

If solids separation is used, both the liquid and solid components of FDE must be considered when choosing the location of the land application area(s).

FDE may be applied to neighbouring or other properties, if this is in compliance with all regulatory requirements.

Other Considerations

Shelter trees planted around the boundaries of the land application area may help reduce wind, and capture aerosols that may potentially get carried off the area.

5.3 Solids Separation

If solids separation is to be used (see Section 4.5), the solids removal infrastructure must be designed to:

- handle the design flow rate of FDE
- remove the fraction of solids listed in design specification, and
- remove the particle sizes required by the chosen land application system.

Method Selection

The following are some common methods for removal of medium to large solids:

- Wedge / Stone-Trap
  Use wedges or stone-traps to remove the largest and heaviest solids. These are suitable for high flow rates.
- Screens
  Use screens to remove small to medium sized solids. The size of particles removed can be controlled by selecting the appropriate screen size.
- Press
  Presses are most effective when used to remove medium sized solids in high concentrations.

- Manual methods
  There are a number of methods available. For example, pushing or scraping solids into a bunker at the end of a feed pad.

The following are common methods used for removal of fine solids:

- Weeping Wall
  Weeping walls may be used for the removal of a range of solids sizes, down to very fine particles. This method is suitable for slow flow rates and usually requires significant intermediate storage.
- Settling Pond
  Settling ponds may be used for the removal of a range of solids sizes, including fine particles. Solids separation by settling may take place in the existing liquid storage, or in a basin designed specifically for this purpose.

There are a number other methods that may be used.

Access for cleaning

Many gravity separation methods (e.g. weeping wall, settling pond) require that the separated solids be removed by machine before being deposited into storage or spread onto the land. Provide appropriate vehicle access and manoeuvring space for the emptying equipment. Use physical dimensions (i.e. width of a sump or stone trap) and materials that are compatible with any equipment used to empty the separated solids.

Easy access to in-line items such as filters and screens must also be considered. Care needs to be taken when machines are used to remove separated solids to ensure liners are not damaged.

5.4 Liquid Storage

This section provides guidance relating to the location and size of liquid storage for FDE.

This document does not cover detailed engineering design or construction of storages. Additional detailed guidance is available through the IPENZ Practice Note 21 Farm Dairy Effluent Pond Design and Construction.

Reassessing Storage Volume

Liquid storage must be designed to meet or exceed the volume requirement listed in the design specification (see Section 4.6). However, the specified volume should be reassessed at this stage to take new or updated information (e.g. the final design of the washdown system) into consideration.

Requirement for Intermediate Storage

If any pumping occurs prior to the FDE entering the main storage then an intermediate storage, or sump, is required. This small storage area is intended to hold any FDE that may build up in the event of a pump failure. If possible, design a sump to hold at least 3 days worth of FDE. Alternatively, specify a backup pump to remove the FDE to the main storage in case of failure of the main pump.

If FDE flows by gravity directly into the main storage, then there is generally minimal requirement for intermediate storage.

Liquid Storage Location

To maximise efficiency, liquid storage should be located near the dairy shed and irrigation infrastructure. However, minimum separation distances (see *FDE Design Standards 2013*) must be observed to maintain a safe and healthy working environment for staff and to avoid the potential effects of unpleasant odours.

The location of the liquid FDE storage should also:

- make use of gravity drainage of FDE where possible
- not be in an area prone to flooding
- not be near surface water bodies or other sensitive areas
- not be on steep slopes running toward surface water bodies or boreholes
- not be in an area prone to groundwater intrusion
- encourage the dispersal of potential odours
- minimise potential adverse effects on neighbours, and
- abide by all regulatory requirements.

Diversion of Clean Water

Good practice dictates that runoff from the dairy shed roof and other clean areas is diverted away from storage, unless the extra water is wanted for a specific reason (e.g. to dilute FDE or to increase the volume of irrigation water available). This avoids having to handle and store water that can safely be directly discharged as stormwater.

Stirrers

It may be necessary to specify equipment to stir the liquid storage to minimise solids build-up and/or crusting. Most FDE storages should have some form of stirring equipment, unless designed specifically as a settling pond. The selection of a stirrer will depend primarily on the design of the storage and the characteristics of the FDE.

Care must be taken to ensure that stirrers:

- are capable of thoroughly mixing the storage prior to, or during, emptying
- do not damage the storage lining, and
- are safe to operate and maintain.

Some storages may be designed as settling ponds to remove solids. In this instance, no stirring equipment is necessary. However, appropriate access must be provided for the removal of the settled solids.

5.5 Solids Storage

Solids storage type

There are many types of storage suitable for solid FDE; these include:

- Stockpile
  This may be either in a bunker or an open stockpile.
- Compost
  This may be either in a bunker or an open stockpile.
- Temporary storage
  For example, solids are stored in a spreading wagon until the wagon is full, and then are applied to land.
- None
  Where application to land is immediate, e.g., removal of solids from a settling pond and directly applied to land.

The selection of solids storage type will depend on all of the following:

- Expected volume of solids
- Intended use of the solids
- Expected storage time
- Available space for storage
- Available equipment for land application, and
- The purchaser's preference

Solids storage location

To maximise efficiency, solids storage should be located near the dairy shed, solids separator, and liquid storage. However, minimum separation distances (see *FDE Design Standards 2013*) must be observed to maintain a safe and healthy working environment for staff and to avoid the potential effects of unpleasant odours.

In addition, the location of the FDE solids storage should:

- not be in an area prone to flooding
- not be near surface water bodies or other sensitive areas
- not be on steep slopes running toward surface water bodies or boreholes
- encourage the dispersal of potential odours
- minimise potential adverse effects on neighbours
- allow for appropriate vehicle access for removal of stored solids, and
- abide by all regulatory requirements.

Leakage and Runoff from Solids Storage

Solids storage areas must be constructed using materials that prevent FDE from contaminating groundwater. Concrete pads are currently the most common way of achieving this.

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

Consideration should be given to covering open stockpiles of separated solids (e.g. with a permanent roof or tarpaulin) to prevent unnecessary leaching of nutrients out of the solids, and wetting of the dry material.

5.6 Liquid FDE Pumping Rate

The pumping rate should be determined and quantified using all of the following factors:

- Soil infiltration rate
- Liquid storage volume (m^3)
- FDE production rate (m^3/day)
- Nutrient budget
- Application area
- Climatic factors
- Hours of operation
- The design limitations of the land applicator

Sufficient allowance must be allowed for:

- moving of equipment
- integration with normal day-to-day operations
- equipment breakdowns, and
- the potential need to defer irrigation.

The pumping rate of the system must be discussed and agreed with the purchaser, and must comply with all regulatory requirements.

Pumping rate may be calculated based on the desired pumping duration by:

$$Q_p = V_s / (D_i * 3.6) \quad (13)$$

where:

Q_p = pumping rate (ℓ/s)
D_i = desired pumping duration (hrs)
V_s = effective storage volume (m^3)

As a guide, allow for at least one to two hours to empty one day's worth of storage. This tends to result in reasonable pumping rates, as demonstrated in the following examples.

Example Calculation:

Assuming a FDE production rate of 50 ℓ/cow/day, 500 cows would produce approximately 25,000 ℓ/day.

Use Equation 13 to calculate the flow rates required to empty one day's worth of storage in one to two hours:

$$Q_p = V_s / (D_i * 3.6)$$

$$Q_{p\text{-}1hr} = 25m^3 / (1\ hr * 3.6) = 7\ ℓ/s$$

$$Q_{p\text{-}2hr} = 25m^3 / (2\ hr * 3.6) = 3.5\ ℓ/s$$

This means that a pumping rate of 3.5-7 ℓ/s would result in a reasonable pumping capacity relative to the size of the storage.

5.7 Hydraulic Design Considerations

The physical and chemical properties of FDE may differ from the properties of clean water. Thus, this section discusses several special considerations that must be observed when designing FDE systems.

Refer to the accompanying *FDE Design Standards 2013* for further specific guidance relevant to the following topics.

General Pipeline Design

When designing pipelines, consider all of the following:

- All friction losses, including friction caused by solids in FDE
- Flow velocities
- The potentially corrosive nature of FDE
- Soil conditions for buried pipelines

- Environmental conditions for surface pipelines
- System and pipeline longevity
- Capital costs, and
- System operating costs

Friction Losses

Appropriate pipe sizes should be selected that do not result in excessive friction losses. Consult the pipe supplier for information on expected friction loss through specific pipe materials.

The supplier's friction loss information may need to be corrected to account for the solids content of FDE. Refer to Table 7 for guidance regarding modified friction loss due to solids content of ≥ 4%. If solids content is less than 4%, the hydraulic properties for clean water may be used in the design of FDE irrigation piping.

Table 7: Pipe friction loss adjustment coefficient, by FDE solids content and pipe velocity (modified from Table 11-1, USDA, 1997).

Pipe velocity (m/s)	**Percent solids (by weight)**					
	≤4%	**5%**	**6%**	**7%**	**8%**	**10%**
	Pipe friction adjustment coefficient					
0.3	1.0	1.5	2.1	2.9	4.0	5.3
0.5	1.0	1.2	1.5	2.1	2.5	4.0
0.6	1.0	1.0	1.0	1.6	1.9	3.3
0.8	1.0	1.0	1.0	1.3	1.6	2.9
0.9	1.0	1.0	1.0	1.2	1.5	2.7
1.1	1.0	1.0	1.0	1.1	1.3	2.5
1.2	1.0	1.0	1.0	1.0	1.0	2.4
1.4	1.0	1.0	1.0	1.0	1.0	2.3
1.5	1.0	1.0	1.0	1.0	1.0	2.2
1.7	1.0	1.0	1.0	1.0	1.0	2.1
1.8	1.0	1.0	1.0	1.0	1.0	2.0
2.0	1.0	1.0	1.0	1.0	1.0	2.0

Example Calculation:

Consider that for a design pumping rate (Q_p) of 7.5 ℓ/s, the pipe manufacture's data suggests a 100 mm (inside diameter) pipe (d) will theoretically result in an acceptable level of friction loss of 1.0m/100m.

However, because the FDE on this property contains 7 % solids, the expected friction loss should be adjusted according to Table 7.

First, the velocity through the pipe must be known, and can be calculates as:

$$Velocity = 4 * Qp / \pi d^2$$

$$Velocity = 4 * (0.0075 m^3/s) / (\pi * 0.1m * 0.1m) = \mathbf{0.95\ m/s}$$

Based on this velocity, the appropriate adjustment coefficient (from Table 7*) is approximately 1.2. The expected friction loss may be calculated as:*

*Actual friction loss = Clean water friction loss * adjustment coefficient*

*Actual friction loss = (1.0 m/100m) * 1.2 = **1.2 m/100m***

A friction loss of 1.2 m/100m should therefore be considered in the design.

Material Selection

Because of its potentially corrosive nature, corrosion resistant materials must be specified for all components coming into regular contact with FDE.

To avoid contamination of groundwater and surface water bodies, special emphasis must be placed on selecting materials that will not leak.

Water Velocity

Adequate flow rates must be maintained so that solids do not settle in the pipelines or open channels and cause blockages. Pipe slopes between 4-15% are generally considered adequate for gravity drainage (USDA, 1997).

Flushing

It is recommended to build in the ability to flush the entire FDE system with fresh water after use. This avoids solids build-up in the system, and will help avoid potential corrosion issues. Flushing the FDE system with clean water can also reduce the amount of FDE that leaks when shifting irrigator hoses. Note that the flushing water should be irrigated onto the land and not just flushed onto the ground from an open end pipe.

5.8 Collection Infrastructure

The FDE collection infrastructure must be designed to handle the volume and consistency of FDE being produced. The system must be designed to handle the peak flow rate of FDE without blocking, overflowing, or leaking.

Wash-down System

A water supply is required for wash-down of the dairy shed and, periodically, for washing of other areas such as standoff areas and feed pads. Wash-water can form a large proportion of the total volume of FDE produced. Thus, it is important to determine the final specifications of the wash-water system prior to designing the rest of the collection and conveyance system.

Wash-down water is usually supplied from clean bore or surface water.

Consider any available alternative systems to minimise water use. For example, consider the use of recycled water, or harvested storm-water, for washing areas that do not require high quality water (e.g. feed pads, stand-off areas or animal housing areas). Always check local regulatory requirements prior to designing systems that use recycled water.

Initial Collection

In addition to the general hydraulic design requirements outlined in Section 5.7, the collection infrastructure must be able to:

- handle the peak flow rate of FDE into the system
- collect material from all enclosed areas subjected to animal FDE
- avoid potential contamination of groundwater and surface water bodies, and
- comply with all regulatory requirements.

Initial collection may be by a number of different methods. Common FDE collection methods include:

- Hose Wash
- Flood Wash
- Scraping
    - Chain in a groove in the floor
    - Rubber backing gates
    - Scraper attached to a farm vehicle
- Gravity Flow

Slats or Grates

If slats or grates are used, they must be designed to hold their own weight plus the weight of animals, humans, and equipment operating within the collection area.

The openings must be large enough to prevent undue slat or grate blockages yet small enough to reduce risk of animal injury. Common sizes range from 10-45 mm (USDA, 1997).

Other Concreted Areas

The minimum recommended ground slope for yards is 2%, and 1% for all other areas.

5.9 Conveyance Infrastructure

Conveyance to Storage

In addition to the general hydraulic design requirements outlined in Section 5.7, the conveyance infrastructure must be able to:

- comply with all regulatory requirements
- handle the peak flow rate of FDE into the system
- convey all material to storage
- avoid contamination of clean areas, and
- avoid potential contamination of groundwater and surface water bodies.

If solids separation is not undertaken, the FDE may be pumped or gravity drained directly to a storage area.

If solids separation is undertaken, the resultant liquids may be pumped or gravity drained to a liquid storage area. With the solids removed, the hydraulic properties of this liquid are typically very close to those of water. Thus, the conveyance infrastructure may be designed similarly to clean water systems in most cases.

Separated solids must be deposited in a designated solids storage area, or applied directly to land. Conveyance method depends on the method of separation. Some mechanical forms of separation (e.g. press) may be able to deposit the separated solids directly into storage (i.e. solids fall onto a concrete pad or into a spreading wagon).

Conveyance to the Land Application System

In addition to the general hydraulic design requirements outlined in Section 5.7, the conveyance infrastructure must be able to:

- handle the flow rate of FDE into the system
- convey all FDE from the storage to the land application area
- maintain an acceptable level of pressure loss
- avoid contamination of groundwater and surface water bodies, and
- comply with all regulatory requirements.

Pipelines running downhill from the storage must have appropriate measures to prevent the siphoning of the storage, and to control the emptying of the pipelines (e.g. vacuum breakers, hydrant valves).

It is recommended to build in the ability to flush the entire FDE conveyance system with fresh water after use. This avoids solids build-up in the system, and will help avoid potential corrosion issues. Flushing the FDE system with clean water can also reduce the amount of FDE that leaks when shifting irrigator hoses.

Pumping stations are covered in detail in Section 5.11.

Back-Flow Prevention

Because of the potential for contamination, a FDE system design must include backflow prevention if it is to be connected to a freshwater source. This includes systems where FDE is injected into freshwater irrigation systems that are connected to a groundwater supply or surface water source.

Local regulations will dictate the type of back-flow prevention device necessary. In the absence of a local regulation, a reduced-pressure zone (RPZ) back-flow prevention device or an air-gap separation is recommended.

Hydrants

Hydrants provide a connection point between land application systems and a buried mainline. Traditional irrigation hydrants that "T" into the mainline may not be adequate for FDE system, as solids in the FDE can settle in the dead section of the mainline causing blockages.

Where solids are present, consideration should be given to using hydrants that break into the mainline such that all of the flow of FDE is diverted out of the mainline to the irrigator.

Appropriate provisions must be included in the design to prevent siphoning of the storage and to control the emptying of the pipelines (e.g. vacuum breakers, hydrant valves).

It is recommended to build in the ability to flush the entire FDE conveyance system with fresh water after use.

5.10 Sprinkler/Emitter Selection and Layout

Sprinklers must be selected and spaced to provide the desired depth, intensity, and uniformity of FDE application. This is achieved by selecting the correct combination of sprinkler spacing, nozzle size, and operating pressure, all of which must be listed in the final system specification.

The manufacturer's coefficient of uniformity (CU) or distribution uniformity (DU) data should be used to select the optimum layout. If the manufacturer's data is not available for the required sprinkler spacing and operating pressure, designers must determine CU and DU by using appropriate sprinkler overlap software or formulae.

Designers should also account for the following:

- Adjust still-air sprinkler spacing for windy conditions.
- For windy areas (average wind speed >10 km/h), use single jet sprinklers in preference to twin jet sprinklers.
- To reduce the potential for spray drift, design for lower operating pressure and larger droplets in windy conditions.
- Use more closely spaced sprinklers whenever practical.
- Keep sprinkler operating pressures within the manufacturer's recommended pressure ranges. This will help prevent misting at high pressures, and poor distribution at low pressures.
- Where elevation changes exceed 5% of sprinkler operating pressure, incorporate elevation variations into the calculations of sprinkler pressures.
- If practical, design systems so that sprinkler laterals or lines are oriented for prevailing winds to flow across them. This minimises the likelihood of over-application by reducing the likelihood that wind will blow FDE from one emitter onto areas where FDE is already being applied by other emitters.
- Incorporate appropriate solids removal processes. This will help avoid nozzle blockages.
- Consider the solids content of the FDE, which may have effects on the spray pattern of certain sprinklers. This in turn may affect application uniformity and efficiency.

5.11 Pumps and Motors

In selecting and specifying a pump and motor for a FDE system, consider all of the following parameters:

- Design Flow Rate
- Total Effective Head
  This is the total pressure the pump has to operate against at the design flow rate.
- Power Requirement
  This depends on the flow rate and total effective head.
- Suction Lift
  Pumps are normally selected according to the above parameters and then checked to see that the suction lift capacity is adequate.
- Servicing and Cleaning
- Solids Content of FDE
  The solids content of the FDE may have an effect on the reported performance and operating life of pumps. Consider pumps ability to handle sand and grit.

Pump Flow Rate

In most cases, this is the easiest parameter to select, as it is based on the application intensity of the system, which will already have been established (see Sections 4.4 and 5.1).

When sizing a FDE pump, it is recommended that a safety factor be added to the design flow rate to account for variation in FDE consistency and wear and tear on the pump (refer to Table 8).

Total Effective Pump Pressure

The total effective pump pressure is the total pressure the pump will impart to the FDE while pumping at the design flow rate. The total effective pump pressure will be based on the:

- required operating pressure of the sprinklers
- elevation difference between the liquid surface of the storage and the sprinklers
- friction loss through the distribution infrastructure (including the pump, pipes, valves, and fittings), and
- suction lift requirement.

When sizing a FDE pump, it is recommended that a safety factor be added to the design pressure to account for variation in FDE consistency, and wear and tear on the pump (refer to Table 8).

Safety Factor

Add the additional capacity factors in Table 8 to the calculated pump duty when specifying a pump intended for FDE.

Table 8: Recommended safety factors for pump duties

Pump specification	Additional capacity (%)
Flow rate	10-20
Pressure	10

Pump Type

Many types of pumps are available for pumping FDE, but not all 'effluent pumps' will be suitable for all types of FDE. While closed impeller centrifugal pumps are the standard for "clean water" irrigation, this may not be the case for FDE.

Pump selection for FDE is highly dependent on the solids content. Special emphasis must be given to selecting pumps that are able to handle the solids content of FDE without blockages or excessive wear. Figure 5 may be used as a guide to selecting an appropriate type of pump.

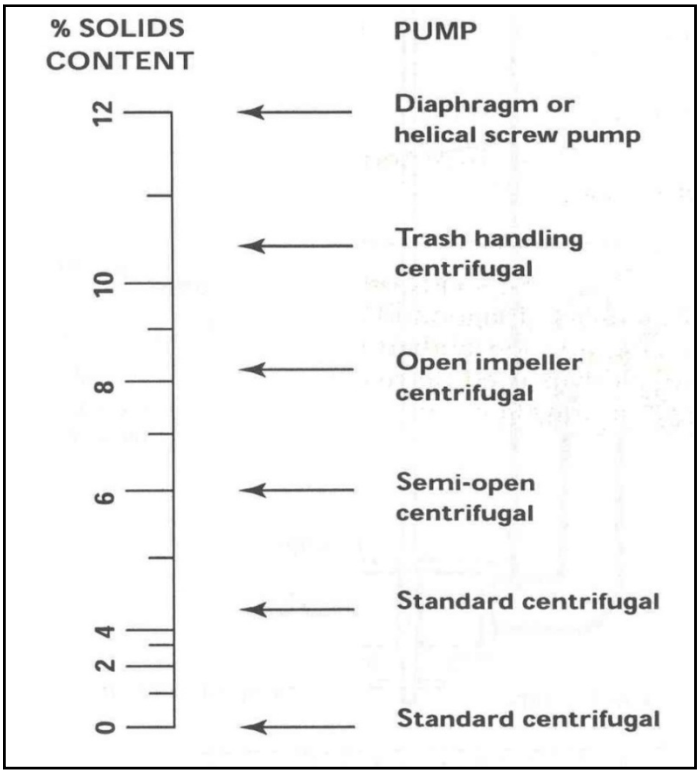

Figure 5: Pump selection guide (modified from: Tyson, 1995)

Pump Efficiency

Pumps should be selected so that they operate at or near their maximum efficiency points as much as is reasonably possible. As different pumps have different levels of efficiency, pumps with the highest level of efficiency at the operating point should be selected, subject to acceptable capital and operating costs.

Pump Motor Efficiency

Pump motors vary in their ability to convert electrical energy to the mechanical energy necessary to drive pumps. High efficiency motors are increasing in availability, and should be selected in preference to lower efficiency motors.

Motors must be properly sized and controlled, regardless of the standard of motor efficiency.

Pump Suction Issues

In general, minimise suction lift as much as possible. This will help maintain peak performance of the pump, and will avoid pump cavitation.

Ensure that suction lift is within the specification of the selected pump through the whole range of expected operating conditions. The allowable suction lift by a particular pump will depend on many factors, including the construction of the pump, atmospheric pressure, water vapour pressure, friction losses, and the specific gravity and viscosity of the FDE.

More detailed information about pump suction issues may be found in Irrigation New Zealand's *Irrigation Code of Practice and Irrigation Design Standards* (INZ, 2007).

Servicing and Cleaning

Emphasis must be placed on safety and ease of servicing and cleaning, as this needs to be done regularly. Locate the pump where it is easily accessible. Floating pumps require special safety considerations.

Provide a cleaning and servicing schedule along with the final system specifications.

5.12 Electrics

All electrical systems must be fit for purpose. They must also be designed to meet local and national electrical standards and requirements.

Electrical systems for pumps should include all of the following:

- A starter type that meets local lines company and energy supplier requirements
- Running timer
- Ammeter
- Total hour meter
- Power factor correction (where appropriate)
- Running light, and
- Appropriate monitoring and control equipment

5.13 Automatic Controls and Alarms

Automatic Controls

It is strongly recommended that all systems are designed with automated shut-down in case of system failure. Safety shutdown controls must override restart controls, so that full protection is maintained.

Install high and low pressure cut-offs on the FDE pumping system.

For travelling FDE irrigators, install an automatic shut-down system when it stops moving for more than 5 minutes. Consider automatic notification of the farm manager.

For solid-set sprinkler systems, consider installing a timer to turn the FDE system off after a pre-programmed time. This will avoid accidental over-application.

If more automatic control is being contemplated, consider the following:

- Automatic restarting after loss of power.
- Automatic starting or stopping from remote locations.

- Restart attempts should be minimised if other problems are likely.
- If the central controller is installed outdoors, house it in a waterproof cabinet.

All control systems must be designed to meet local and national electrical standards and requirements.

Alarms

It is strongly recommended that alarms are 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.

Consider installing an alarm to indicate when the system has been automatically shut down for any reason.

5.14 Measurement and Monitoring

The purpose of measurement and monitoring is to provide information to assist with system management and tracking of performance. It also provides the basis for reporting for compliance with regulatory requirements.

The system specification must describe how system performance can be measured, and must ensure that suitable sites and equipment are specified to facilitate the collection of the data required.

Liquid Storage

Install a marker or water level measuring device 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

Flow rate measurements are required by the system operator to calculate how much nutrient has been applied to specific land areas.

Most systems should include a flow measuring device on the delivery side of the FDE irrigation pump to measure the volume and flow rate of liquid FDE being applied to land.

If no flow measuring device is specified, some other way of determining the flow rate must be prescribed. The method for determining flow rate must be described in the system's operation manual and training material (see Section 6.4).

Always include the provision for a flow measuring device to be installed at a future date, even if it is deemed unnecessary to include a device in the original design. Typically, this will mean installing a length of straight pipe on the outlet side of the pump.

Also consider installing a flow measuring device to monitor water usage during washdown.

Always consider the nature of the particular fluid being pumped when selecting any flow measuring device. Some devices will not be compatible with FDE.

Pump Pressure

Install a pressure gauge or pressure test point at the pump outlet and at the applicator to enable regular checking of performance.

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

Fit an air-bell (or similar) to protect a pressure gauge from corrosion and blocking. Fit isolating stopcocks (or similar) so pressure gauges can be turned off to prevent damage when not in use.

Soil Moisture

Knowledge of soil moisture is necessary for the FDE irrigation manager to determine the timing and quantity of FDE to be applied. A good design will describe how soil moisture is to be monitored. Separate monitoring may be required for each FDE application management zone if soil types or application depths vary.

Some common forms of soil moisture monitoring include:

- Permanent Sensors
  These provide a continuous measurement of soil moisture at a particular site. Because the sensor is stationary, soil moisture at other parts of the property needs to be estimated.
- Hand-Held Sensors
  These provide a single measurement of soil moisture at any location. These require some owner initiative to work correctly, but soil moisture may be checked at any number of locations, and on any desired schedule.
- Contractors
  Engage a third-party "irrigation scheduling services" to measure soil moisture. These contractors usually provide soil moisture measurements at fixed locations, on a fixed schedule (i.e. once per week), and can prescribe areas of the property that are fit for application.

Spatial Distribution of Applied FDE

Designers should consider options for tracking the locations where FDE has been applied. Automatic records of the spatial distribution of applied FDE can help the purchaser to best schedule future applications, as well as demonstrate compliance with regulatory requirements.

Data Logging / Telemetry

Designers should consider data logging and telemetry options for measurement, monitoring, and control systems. Automatic logging of system performance parameters can provide invaluable information to the system operators. Tracking past performance can help optimise future performance, as well as demonstrate compliance with regulatory requirements.

5.15 Safety Considerations

The design of an FDE system must ensure the safety of those operating and maintaining it. The following items are particularly important to consider when designing any FDE system (USDA, 1997):

- Guard all Moving Parts
  Ensure that any potentially dangerous moving mechanical parts are guarded.
- Earth Electrical Equipment
  Ensure that all electrical equipment is properly earthed and protected from moisture.
- Barriers
  Fence around storage ponds to keep both humans and animals away from the potential drowning hazard.
- Non-Slip Surfaces
  Because work must sometimes be conducted inside barriers, consider using non-slip surfaces next to storage ponds to minimise the likelihood of workers falling in.
- Stabilised Pontoons
  FDE pumps and/or stirring equipment are occasionally installed on a pontoon floating in the storage pond. If a pontoon is used, ensure that it is stable, and fitted with suitable devices to prevent it from flipping over.
- Emergency Escape
  Install equipment in liquid storage units to aid in the rescue of a person that has fallen in, e.g., rope, ladder, or floating inner tubes.
- Ventilation
  Avoid over-exposure to hazardous gases potentially present in FDE (e.g. carbon dioxide, ammonia, hydrogen sulphide, methane, carbon monoxide) by providing good ventilation around all areas of the FDE system.
- Training
  Provide training for system owners and operators that includes instructions on how to operate and maintain the FDE system in a safe manner.

Provide adequate safety information, including emergency protocols, in the operations manual.

5.16 System Specification Report

A design report and plan summarising the final system specifications must be provided to the purchaser. This document will describe the final system composition and what it will be capable of achieving.

Complete the system specification report in sufficient detail that:

- quotations for the supply and installation of the system may be obtained, and
- it may be reviewed by another designer, if desired by the purchaser.

All of the following information must be clearly visible within the system specification:

Designer Information

- Name of supplier
- Contact details of supplier, e.g., address, phone, fax, and email
- Name of designer(s)

Purchaser Information

- Name of purchaser
- Contact details of purchaser, e.g., address, phone, fax, and email
- Name of property
- Location of property

Input Information and Assumptions

Supply input values determined during the initial site investigation (refer to Table 1):

- Site layout
- Soils information
- Climate information
- Regulatory requirements
- Farm management needs
- FDE characteristics

System Specification

- Size of the application area(s)
- Land application method
- Range of application depths the system is capable of applying
- Range of nutrient loadings the system is capable of achieving
- Application intensity
- Expected application uniformity
- Solids separation method, if used
- Size of particles removed if solid separation used
- Pumping rate
- Pump operating pressure
- Irrigator operating pressure
- Expected pumping frequency and duration
- Storage type
- Storage volume
- Plan, showing the locations of the proposed infrastructure and the land application area(s)

Bill of Materials

The bill of materials and associated costs must provide a clear description of items and services to assemble the designed system.

This will include some or all of the following:

- Description of materials with rating or classification:
    - FDE collection infrastructure (e.g. grates, concrete, etc.)
    - Materials for storage construction
    - Solids separation equipment
    - Stirring equipment
    - Irrigation system components
    - Pipes and fittings
    - Pumping and related equipment
    - Electrical equipment
    - Any other necessary components
- Required quantities of each item

Compliance Information

The system specification must describe how the FDE system will comply with the relevant regulatory requirements, including resource consent conditions.

Expected Operating Costs

- Expected labour costs
- Expected energy costs
- Routine maintenance costs (time and materials)

Express operating cost as a cost per animal (e.g. $/100 animals) as well as cost per unit time (e.g. $/yr).

Technical Analysis

The designer must provide sufficient information to the purchaser to show that the technical analysis required to arrive at the chosen design has been carried out (e.g. nutrient budget, storage sizing calculations).

6 IMPLEMENTATION

The fourth stage of developing a farm dairy effluent (FDE) system is to supply, install, and test the system to ensure that it operates according to the system specifications. Instruction and training are also to be provided for the system operators.

This stage of the development may be completed by the same people as the other stages, or it may be completed by someone with skills specific to this area.

6.1 Quoting

A quotation based on the system specification must be supplied to the purchaser, so that all parties are clear about what is going to be provided. The following information must be clearly visible within any quotation:

Schedule of Materials and Services

The schedule of materials and services must provide a clear description of what is to be provided under the contract so that it is very clear about what is and is not being supplied.

Any deviation from the Design Bill of Materials must be clearly identified

The schedule of materials and services may include some or all of the following:

- Description of materials with rating or classification:
    - FDE collection infrastructure (e.g. grates, concrete, etc.)
    - Materials for storage construction
    - Solids separation equipment
    - Stirring equipment
    - Irrigation system components
    - Pipes and fittings
    - Pumping and related equipment
    - Electrical equipment
    - Any other necessary components
- Supplied quantities

Costings

The quote may be a "single price for full supply and installation" or may tabulate some or all of the required items individually.

Items for which itemised costs may be specified may include some or all of the following:

- Material costs for all components
- Installation costs for all components
- Exchange rate assumptions and variations to costs if they change (as far as possible, quotes must be based on a fixed price)

- Any optional items in the design or quote
- Any contingencies included in the costing
- GST

The quotation must state any potential variations to the list and how subsequent costs will be justified. If extras costs are commonplace, or can be foreseen, these must be documented.

Warranties

A written minimum 12-month warranty should be offered, specifying items covered and how the warranty is going to be serviced. The warranty must include:

- the period of cover, and
- identification of who is responsible and what they are responsible for.

Expected reliability and life of the system must be made known to the purchaser.

Delivery Times

List estimated delivery times for all items. If any variations to delivery times occur, explain this to the purchaser.

Servicing

System servicing procedures and conditions must be made known to the purchaser. This should include charge out rates and expected response times.

6.2 Installation

The system must be installed in accordance with the system specifications prepared by the designer, and agreed by the purchaser. If any deviation from the system specification becomes necessary, the purchaser must be notified. The system designer and the purchaser must both accept any variation to the original specification prior to installation.

Recognised industry good practice must be used for installation of all FDE systems. This means complying with all regulations, engineering standards, environmental requirements, and health and safety requirements. In particular, reference should be made to any relevant standards for the various parts of the system and compliance certificates issued, where appropriate.

If deviating from any of the recognised standards or good practice, the purchaser must be notified, and the decision to accept a different standard made by the purchaser. All deviations should be documented and signed by the parties.

6.3 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. This process must demonstrate compliance with regulatory requirements, including resource consent conditions.

Any variations from the original design must be documented on an as-built plan or in the commissioning report and supplied to the purchaser.

The designer(s) and installer(s) are responsible for verifying their portion of the work.

Evaluation Process

The installed system must be tested to determine that the performance standards have been met. The purpose of this testing process is to compare the specified design performance with the values actually achieved in the field.

A standard operating procedure for the evaluation of FDE systems will be developed to guide the testing process. Until this is completed, the design must state how the system is to be assessed for performance and compliance. A certified training programme will also be developed for FDE system evaluators in New Zealand.

Irrigation New Zealand's *Irrigation Evaluation Code of Practice* (2008) may also be used as a guide to evaluating FDE spray irrigation systems.

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 will have to be made, and the consequences of the differences between assessed need and proposed system performance explained to the purchaser.

The commissioning report will include:

- Date of commissioning
- Procedures followed during commissioning
- Results of performance testing, and
- 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, or following making changes to the system.

The plan must provide accurate locations, dimensions and sizes of all key components in the system. This is particularly important for items buried underground. This plan must indicate areas where effluent can and cannot be applied.

Technical Supporting Information

Technical information is required to support the design and analysis. It may be required for an independent evaluation of the design. Technical information will be required:

- for maintenance;
- if changes to the design are contemplated;
- to compare current performance with performance changes over time; or
- to assess the design if something goes wrong.

The technical supporting information should include:

- design schematics of all structures (e.g. the liquid storage)
- specifications of solids separation equipment
- specifications of pipelines and drains
- pump characteristic curves showing duty points
- sprinkler performance curves
- specifications of irrigators, and
- specifications of electrical equipment.

This technical information may be included as part of the system operation or maintenance manuals (see Section 6.4).

6.4 Manuals and Training

Appropriate manuals and training material must be provided with every FDE system. Place emphasis on presenting information clearly. Use plain language and diagrams wherever possible, as this information will be used by a range of different farm staff, from managers to labourers.

Operation Manual

A system operation manual must be provided, and should 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 should 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 must be made available for the purchaser and system operator that covers all of the main items in the operation and maintenance manuals.

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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: Site Visit Checklist

Item	Description	Complete
Site layout		
Map	Obtain a copy of the property map, including all current infrastructure and land features, and any planned infrastructure.	
Topography	Identify land features that may affect the design of the FDE system, including land slope, gullies, surface water bodies, flood risks, etc.	
Design Area	Identify the potential areas for dairy sheds, storage locations, and for land application.	
Fencing	Identify potential fencing arrangements, and how it will affect FDE land application equipment.	
Shelter	Identify the natural or artificial wind breaks that are present or will be required.	
Land Restrictions	Identify protected areas or covenants on titles, and the location of any sensitive areas.	
Energy Source	If power is required, locate the nearest supply and identify its limitations.	
Water Supply	Determine if there is a suitable water supply available for the washdown system.	
Vandalism	Identify any potential for vandalism.	
FDE characteristics		
Nutrient Concentration	Determine the N, P, and K concentration likely to be in the FDE.	
FDE Production Rate	Determine how much FDE will be produced each day, month, and year.	
Solids Content	Determine the percentage and particle size distribution of solids in the FDE	
Soils information		
Soil Type	Identify the types and locations of the soils on the property.	
Profile Available Water (PAW)	Determine the depth of water the soil can hold that is available to plants.	
Infiltration Rate	Determine the speed at which the soil absorbs water. This may be affected by other soil or landscape features such as pans, drains, soil compaction, or ground slope.	
Drainage	Identify any areas with poor or enhanced drainage. This may include natural or artificial soil drainage.	
Soil Type	Identify the types and locations of the soils on the property.	

Item	Description	Complete
	Climate information	
Rainfall	Obtain rainfall records for the property, or from the nearest weather station.	
Evapotranspiration	Determine typical plant water demand for the property.	
Wind	Determine the prevailing wind directions for the property.	
	Farm management information	
Animal Numbers	Determine the number of cows milked in the dairy shed throughout the season – determine average and peak.	
Milking Schedule	Determine the milking schedule, i.e., the number of milkings per day, or seasonal milking schedule.	
Wash-water Use	For existing systems, determine the type of washdown system and its water use rate.	
Labour	Determine the skill level of the labour available to operate the system.	
Future Flexibility	Identify the likelihood and timing of future changes, e.g., an increase in stocking rate.	
Process Control	Identify the purchaser's preferences for automated checks and controls.	
Delivery	Determine the date by which the system is required to be operational.	
Health & Safety	Identify any health and safety issues pertinent to the site.	
Other	Identify any other issues relevant to the purchaser.	
	Regulatory requirements	
Resource Consents	Check that all necessary resource consents have been obtained. Determine if other resource consents will affect the FDE system.	
Local Requirements	Be aware that there may be local regulatory requirements regarding the storage or land application of FDE.	

Notes:

Appendix B: Design Specifications List

The following items must be listed in the design specifications, prepared after Stage 2 of the FDE system development process. They will define the performance parameters that the final system will need to achieve. The system designer will use them, along with the information obtained during the initial site investigation, as input values to the detailed design stage (Stage 3).

Parameter	Unit(s)	Specification
Land application area	ha	
Yearly nutrient limits	kg N/ha kg P/ha kg K/ha	
Limiting nutrient	N, P, K, or other	
Maximum allowed application depth	mm	
Minimum application depth system must be capable of	mm	
Maximum allowed application intensity	mm/hr	
Required liquid storage volume	days m^3	
Required solids storage volume	days m^3	

A complete design specification must also state all input assumptions (soils, climate, FDE characteristics, etc.)

Appendix C: System Specifications List

The following specifications must be listed in the final design documentation, along with a brief description of how they were derived. These will help the purchaser understand more about how the system will operate, and will provide confidence that the design has been conducted to an adequate level of detail. They may help the purchaser decide between otherwise equally performing systems.

Parameter	Unit(s)	Specification
FDE collection, storage, and land application		
Land application area	ha	
Achievable application depth range	mm	
Application intensity (may be a range)	mm/hr	
Application uniformity	% ratio	
Expected nutrient application per event	kg N/ha kg P/ha kg K/ha	
Particle sizes removed (if used)	mm	
Pumping rate	ℓ/s m^3/hr	
Expected pond emptying schedule	days hrs/day	
Pump operating pressure	m kPa	
Irrigator operating pressure	m kPa	
Effective liquid storage volume	days m^3	
Effective solids storage volume	days m^3	

Labour Requirements		
Yearly operational labour requirements	hrs/yr	
Yearly maintenance requirements	hrs/yr	
Hours required for operation	hrs/100 cows	
Hours required for routine maintenance	hrs/100 cows	
Energy Requirements		
Pumping system energy rating	kW	
System pumping efficiency	kWh/m^3	
Expected Operating Costs		
Expected annual operating cost	$/yr	
Operating cost per animal	$/cow/yr $/100 cow/yr	

In addition to the items in the above table, a complete system specification must also include all of the following:

- Input assumptions (soils, climate, FDE characteristics, etc.)
- Plans
- Gutters / drains sizes and layouts
- Pipe sizes / layout
- Specification of land application equipment
- Specification of stirrers (if used)
- Specification of electrical equipment
- Specification of alarms and monitoring equipment
- Technical supporting information

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