Discussion Paper: A potential methodology for assessing farm dairy effluent systems

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February 2019

Report for Environment Southland

Client Report Number: RE450/2018/076

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Contents

1. Executive Summary

This report documents the requirements for assessing Farm Dairy Effluent (FDE) systems in a consenting process. The purpose of this is three-fold. Firstly, it attempts to provide a framework for evaluation of new FDE application methods. Secondly, it attempts to provide an example of a transparent and sufficiently rigorous assessment protocol that ensures consented FDE systems are realistic, practicable and deliver high standards of environmental performance. Thirdly, it reviews a system as an example of how the assessment framework could be applied in Southland.

A review of research literature suggests that there are 3 key aspects of any proposed FDE system that need particular consideration to ensure the FDE resource is utilised efficiently and risks to the environment are minimised. These are:

- Ensuring that the proposed FDE system contributes to balanced pasture nutrition and maintenance of soil quality.
- The use of an assessment process that ensures the hydraulic loading attributes of the proposed FDE system are appropriate for the landscape where FDE is to be applied. Identification of key contaminant pathways and key contaminants of concern are important considerations in this process.
- Consideration of the nitrogen (N) loss risk (to water) that any FDE system could pose.

Associated with each of the above key considerations are minimum information requirements that are needed to assess whether a FDE system will deliver a high standard of environmental performance. A template designed to standardise and streamline the presentation and assessment of the required information is described and framed within a Southland context, recognising that the proposed Southland Water and Land Plan (pSWLP) sets out some specific requirements for how dairy effluent systems will be assessed in the future. A case study example is then presented to document how this template and assessment process could be applied to an actual FDE system.

2. Background

In New Zealand, Regional Councils are required to assess applications for resource consent. This process involves determining the level of environmental effect the activity will have and assessing against policy whether the scale of effects are appropriate. How activities are assessed in resource consent processes can vary between regions. Whilst the burden of proof is on an applicant to demonstrate how an activity might affect the environment, the type and quality of information provided by applicants is inconsistent both within regions and across the country. Farm Dairy Effluent (FDE) irrigation to land is an activity that needs to be considered by all regional councils, with many requiring resource consent. Because new and novel effluent management systems continue to be developed by farmers, engineers and rural professionals, a consistent and robust assessment process by consenting staff is desirable to ensure that proposed FDE management systems are realistic, practicable, deliver high standards of environmental performance, and that the effects of discharge using these systems are able to be assessed. To help achieve this goal, Environment Southland, supported by funding from Envirolink, has approached AgResearch to provide guidance in the development of such an assessment template.

3. Project Aims

1. To update (based on recent research) management guidance for the application of FDE to land in Southland.
2. To develop an assessment template that sets out information requirements for applicants wishing to adopt FDE technology.
3. To provide assessment criteria for regional councils to use when reviewing applicant information.
4. To provide an example of the application of these assessment criteria.

This template and assessment criteria will be utilised by Council staff, rural professionals and effluent system developers to better understand consent information requirements and how that information will be assessed. This will make it easier for a new technology to pass resource consent requirements, aid the writing of practical and appropriate consent conditions and may also help to reduce consenting costs by making the process more efficient. The template could potentially be used to ensure national consistency in how any new FDE irrigation technology is assessed in resource consenting processes.

4. Approach

The key components of this project were to:

- briefly review any recent literature that documents the performance of effluent management systems;
- identify the key environmental considerations for FDE management systems;
- establish minimum information criteria that can be used to assess the information provided by an applicant;
- provide guidance to assess whether tools (e.g. the Overseer® Nutrient Budgets model) have been appropriately used; and
- provide a template assessment procedure, using the 'Clean Green' effluent system in Southland as an example.

There are a number of different parts to FDE systems that include effluents collected from the milking parlour and yard or from animal feeding and loafing areas. These materials, which can vary widely in terms of solids and nutrient contents, can be stored, treated or even exported from the farm. Most FDE is now returned to land via spray irrigation methods. The scope of this report is therefore confined to considerations that are needed for the safe storage and application to land of effluents and has been prepared to account for the risks posed by both liquid (hydraulic loading risk) and solid (nutrient loading risk) forms of FDE.

5. Recent developments in FDE irrigation systems

The management of FDE in New Zealand has historically involved the collection of daily wash down effluent into a concrete sump and subsequent immediate application to pasture using a twin-boom travelling irrigator. Since the late 1990s there has been greater uptake of recently-researched good management practices for FDE application to land, in particular the adoption of a deferred irrigation strategy (pond storage when soil moisture is close to, or at, field capacity). In more recent times low application rate sprinkler systems have also been developed and increasingly used as part of some FDE management systems.

The combination of low soil infiltration rates and wet soil conditions on sloping land will provide the greatest risk for overland flow generation. Sloping land poses a high risk of overland flow generation and surface redistribution when FDE is applied using high application rate travelling irrigators. Low rate sprinkler application systems are therefore ideal for these high risk scenarios to ensure that application rate criteria can be met for soils that have lower infiltration rates. This strategy of using low rate FDE application methods was initially developed to avoid or minimise surface ponding of FDE and ensure applied FDE moved into the soil profile, thus allowing for greater attenuation of effluent contaminants (Monaghan et al. 2010a). For a number of practical and environmental reasons, it was recommended that such low rate application systems were run in accordance with the principles of deferred irrigation, thus minimising environmental risk as much as possible.

Recent research documented by Laurenson et al. (2017) has explored the potential additional benefits of combining low rate FDE application methods with a strategy of applying low depths per application (2 mm per day or less). We hereafter refer to this approach as “low rate, low depth applications”, or LRLD. The hypothesis underpinning this approach was that a high degree of nutrient attenuation is possible when FDE is applied to land using LRLD application methods, even when soils are relatively wet. If proven correct, such a strategy could reduce effluent storage requirements, and thus avoid much of the cost of building or retrofitting existing effluent systems, including circumstances when an off-paddock livestock housing facility is installed. An additional potential benefit of this system is that it can also provide an option for applying effluent to land on occasions when effluent ponds are full, as sometimes happens following prolonged periods of wet weather during spring. Of note is that the experimentation reported by Laurenson et al. was conducted on a landscape that can be described as high risk: the site had a soil with artificial drainage present and received FDE during times when soil conditions were typically wet. These landscapes are common to many parts of Southland, Otago, Canterbury and Manawatu where large areas of Pallic soil orders are now used for dairy farming. A relatively large proportion of these soils are artificially-drained to overcome drainage limitations caused by soil fragipans that can occur at 60 – 90 cm depth, thus helping to minimise soil compaction and surface runoff from these less resilient soil units.

Results presented by Laurenson et al. (2017) generally supported their hypothesis: whilst LRLD application of effluent to pastoral land during winter led to a greater quantity of N lost to water, these losses were small in comparison with those associated with cow grazing practices (i.e. background losses). Annual losses of phosphorus (P) and *Escherichia coli* (*E. coli*) were not affected by the contrasting FDE application methods, although a temporal effect was observed whereby greater losses were observed during late winter and spring drainage in the LRLD treatment compared to autumn in the treatment that employed a travelling irrigator to apply an equivalent annual depth of FDE. Their overall conclusion was that there was limited evidence of adverse effects of the LRLD strategy, particularly when compared to the considerably greater contaminant fluxes associated with *in situ* grazing of forage crops and pastures.

Whilst the LRLD strategy was proposed as a viable alternative to investing in large storage ponds or retrofitting existing ponds, vigilant monitoring of soil and climatic conditions was noted to be incumbent to the successful operation of these systems, particularly when soil conditions were wet (i.e. soil water deficits (SWDs) were practically zero).

These monitoring attributes include:

- FDE application rates of 4 mm h^{-1} (or less);
- FDE application depths of 1 mm (or less), made twice (or less) each day i.e. 2 mm in total day^{-1}. Within a day, there was a 6 hour interval between each application;
- Climate: rainfall in the preceding 24 h was less than 4 mm; air temperatures were greater than 4°C; and average wind speed was less than 4 m s^{-1} at the time of application. There were, therefore, days when effluent was not applied; and
- FDE scheduling did not exceed a target cumulative FDE total N loading equivalent of 80 kg N ha^{-1} over cool-wet periods. This threshold is based on the scheduling employed by Laurenson et al. over the winter and early spring period and was formulated to avoid excessive inputs of N during periods when plant uptake is low (less than 1 kg N $ha^{-1}day^{-1}$).

The above guidelines do however recognise that what constitutes an acceptable nutrient/FMO loss risk will be dependent on the regulatory and environmental setting.

Another recent development in effluent management technology are the umbilical delivery systems now available on the market. Umbilical systems are promoted as an option for shifting large volumes of FDE in a relatively short space of time. They also have the potential advantages of more even spreading of FDE; proof-of-placement; less spray drift (assuming the FDE is applied to soil via a trailing shoe/hose or is injected); and will generally cause less disturbance to laneways and paddocks compared to slurry tanker methods. FDE applications made via umbilical systems still need to adhere to the scheduling criteria as outlined later in this report, however, to ensure FDE constituents are attenuated by the soil.

A very recent development in effluent technology is the flocculation of FDE to produce clarified water that can be used for recycling. Cameron and Di (2019) describe a treatment system that used polyferric sulphate as a coagulant to flocculate and settle colloidal particles in FDE. The resulting liquid stream was found to have greatly reduced turbidity levels (a 97% reduction in nephelometric turbidity units (NTUs)) and concentrations of *E. coli* (reduced by more than 99%), TP (reduced by 94%) and N (reduced by 70%). Land application of this clarified FDE water was found to have no adverse impact on plant growth. This emerging technology is now promoted as ClearTech (https://www.cleartech.co.nz/) and potentially offers 2 distinct advantages:

1. The concentrations of key water contaminants are greatly reduced, as noted above (thus minimising ***contaminant load risks***).
2. The potential recycling of clarified FDE liquid at the dairy shed will greatly reduce the volumes of FDE that need to be stored and eventually applied to land (thus minimising ***hydraulic loading risks***).

6. Key environmental considerations for an FDE irrigation system and suggested minimum information criteria

The sections below provide scientific background material and present the minimum information criteria needed to assess an effluent system against key environmental considerations. Provision of this information should allow a consenting officer to determine whether any particular FDE irrigation system is realistic, practicable and is likely to achieve an adequate standard of environmental performance. This assessment does not provide criteria to assess the appropriateness of a system for a specific environmental setting as this will be determined on a case-by-case basis and is dependent on the policy framework.

6.1 Contribution to balanced pasture nutrition and maintenance of soil quality

Because effluent is a particularly rich source of nitrogen (N), phosphorus (P) and potassium (K), it makes good economic sense to ensure that inputs of these effluent nutrients are matched to provide the agronomic requirements for pasture maintenance on the effluent-treated parts of the farm. The preparation of a nutrient budget will help determine the appropriate areas of a farm that can be treated with effluent. Whilst this type of appraisal step does not specifically address risks to water quality, it does require applicants to go through a planning process that ensures nutrients are efficiently distributed across areas that are to be treated with effluent. An important aspect of this planning is to ensure that nutrient inputs from fertilisers and supplements are adjusted to account for nutrient returns in effluent and nutrient surpluses are therefore minimised. This is particularly important for N (discussed further below) and K where excessive soil accumulation of the latter can potentially contribute to animal metabolic problems. Excessive accumulation of P in effluent-treated soil is also a potential outcome that may increase P loss risk to water, and should thus be avoided by following the planning and appraisal step suggested here.

Maintenance of soil physical quality is an important additional consideration for effluent-treated areas. This recognises that, for some management systems and soil types, it is potentially possible to find that soils remain wet for relatively long periods of time and are consequently more vulnerable to compaction incurred due to the effects of soil treading damage by animal hooves. Such decreases in soil quality can compromise air and water exchange between soil and the atmosphere, potentially reducing plant growth and contributing to erosion and surface runoff to waterways. Protocols for assessing such effects can be based on visual inspections and scoring (e.g. Shepherd 2000) or measurement-based procedures that follow standard field sampling and laboratory protocols; findings derived using the latter approach can then be assessed against some of the commonly-accepted measures of soil quality that are documented in Table 1. Minimum information requirements for considering the potential effects of effluent applications on pasture nutrition and soil quality are documented in Table 2.

Table 1. Criteria used for categorizing soil quality using laboratory-based measures for pastures (after Sparling & Tarbotton, 2000; K also assessed using Edmeades et al, 2016). Olsen P thresholds are based on both agronomic data (Roberts & Morton, 1999) and risk of P loss to waterways (from AgResearch field trial data).

Soil test Category		Low	Normal	High
pH	All soils	< 5.5		> 7
Quicktest K	Sedimentary	< 5		> 8
	Allophanic, pumice	< 7		> 10
	Organic	< 5		> 7
Organic C	Allophanic	< 4		> 9
	Other soils	< 3		> 5
Total N	All soils	< 0.35		> 0.65
Mineralizable N	All soils	< 100		> 200
Macroporosity	All soils	< 8		> 30
Bulk density	Sedimentary	< 0.9		> 1.25
	Allophanic, pumice	< 0.6		> 0.9
Olsen P	All soils	< 20		> 40

Table 2. Minimum information requirements for considering the potential effects of effluent applications on pasture nutrition and soil quality.

1	A nutrient budget showing nutrient inputs from fertilisers, supplements and effluent application.
2	Soil test information is presented (P, K and S in particular) that supports the current plan for nutrient inputs to FDE-treated areas and is consistent with the nutrient budget.
3	A plan to routinely undertake soil quality assessments of FDE-treated areas is provided along with descriptions of management actions if pasture nutrition or soil quality problems arise.

6.2 Contaminant loss risk to water posed by the FDE system

The effectiveness of FDE management systems has been shown to vary depending on the associated risk posed by contrasting soil and landscape features. Soil and landscape features such as sloping land, land with artificial drainage and land with either impeded drainage or low surface infiltration rates were identified as typically displaying a high risk of preferential or overland flow of land-applied FDE (Houlbrooke & Monaghan 2010). In contrast, soil types with well-drained, fine structured soils typically exhibiting matrix flow characteristics were deemed to represent a relatively low risk of direct losses of contaminants due to FDE application; indirect losses of N to water from these soils can be relatively high, however, particularly for those that have low Plant Available Water (PAW) contents. A knowledge of contaminant flow pathways is therefore important for identifying which contaminants are likely to pose greatest risk to water quality and for ensuring effluent systems are appropriately designed and matched to landscape features.

6.2.1 Consideration of FDE hydraulic loading and flow pathway risk

Poorly managed FDE land treatment systems may generate surface runoff and preferential flow that can convey large amounts of faecal microorganisms (FMOs), P and ammoniacal forms (NH_4^+ or NH_3) of N from soil to water. Measurement and modelling assessments by Monaghan et al. (2010a & 2010b) have demonstrated that transfers of FMOs in surface runoff or drainage generated due to the application of FDE to land can potentially represent a large proportion of farm-scale losses of this group of contaminants. Figure 1 illustrates the relative importance of the different sources of *E. coli* discharged from a model Southland dairy farm; as noted in Monaghan et al. (2010a), the large contribution resulting from incidental losses of FDE is probably a conservative estimate given the now widespread implementation of stream stock exclusion measures. The information presented in Figure 1 is provided as an indicative portrayal of potential losses to help identify where mitigation efforts can be most effectively targeted and clearly shows that FDE management is an important thing to get right if farm-scale FMO loads are to be successfully managed. This is a particularly important consideration for soil types and landscapes that possess an inherent risk of incidental losses of FDE. Critical landscapes with a high degree of risk include those that exhibit overland flow, artificial drainage or lateral drainage as key flow or contaminant pathways. These landscapes commonly have coarse soil structure, soils with either an infiltration or drainage impediment, or soils on rolling/sloping topography. These risk factors are common to landscapes mapped within the Gleyed, Central Plains, Peat Wetlands, Bedrock/Hill Country, Alpine and Lignite/Marine Terraces zones as well as the Overland Flow, and Artificial Drainage Physiographic Variants (Hughes & Wilson, 2016).

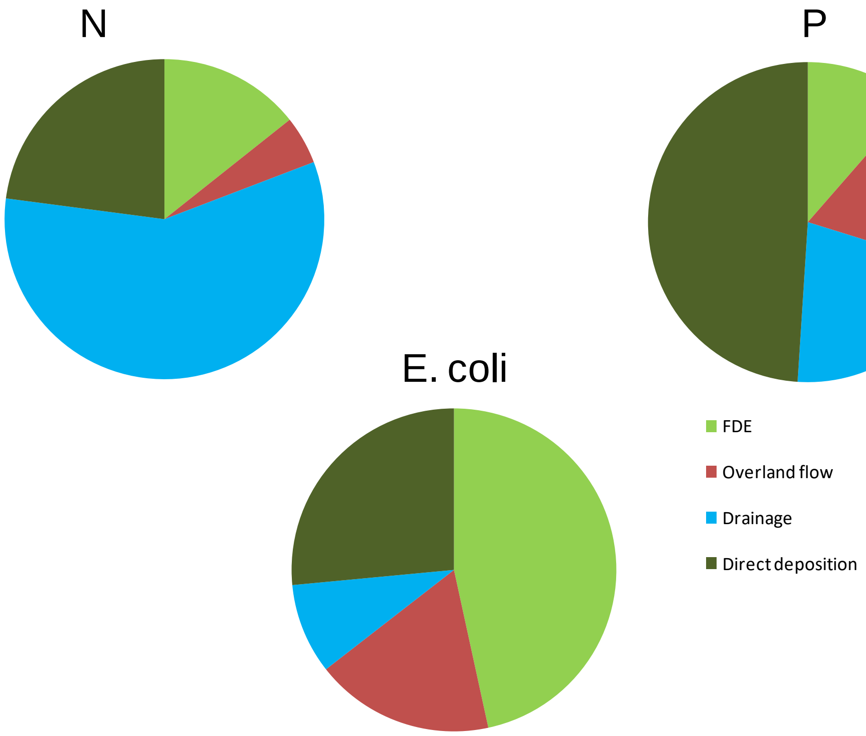

Figure 1. Estimated sources N, P and *E. coli* discharges to water from a model Southland (Bog Burn catchment) dairy farm on naturally poorly-drained soils: (i) direct deposition of faeces to un-fenced streams, (ii) drainage, (iii) overland flow, and (iv) incidental losses of contaminants due to the preferential flow of FDE through mole-pipe drains (one month pond storage assumed). Note that un-restricted access of cows to streams has been assumed to demonstrate the large potential effect this can have on whole-farm contaminant losses (from Monaghan et al. 2010b)

A key consideration to minimise the risks of the direct transfers noted above is to ensure that FDE application rates and depths are carefully matched to soil hydraulic attributes (including available soil water deficit). The critical hydraulic information requirements for assessing FDE systems are FDE application depth (mm), the instantaneous and average FDE application rates (mm/hr), soil infiltration rate and PAW content, and FDE storage requirement criteria. Implicit to these and the points made above is the need for some FDE storage to cope with occasions when climate attributes or soil wetness do not allow FDE to be applied to land. Adherence to these hydraulic attributes is particularly important for helping to ensure the risks of P and *E. coli* transfers to water are minimised. An added benefit of having some FDE storage is the enhanced die-off of faecal microorganisms that can be expected when effluent is stored, which can be particularly helpful for reducing the risk posed by any *Campylobacter* that may be present in FDE. Our understanding is that the Dairy Effluent Storage Calculator (DESC) does not currently have the functionality to calculate how much pond storage would still be required if a LRLD system was proposed; this aspect of the DESC is currently under review by DairyNZ.

6.2.2 Managing N loss risk

Relatively large amounts of N can be returned to land via applications of FDE, adding to the N already cycling through the soil-plant-animal system. Adequate planning and management of these inputs is therefore required to avoid large surpluses of soil N that are vulnerable to transport in drainage to groundwater (or to surface water in the case of mole-pipe pathways of drainage loss) over the following winter.

Most regional councils have established upper N loading limits of between 150 and 200 kg of FDE-N ha^{-1} yr^{-1} and many use these as a guide for allocating land area for FDE irrigation (Monaghan et al. 2007). These guidelines were generally premised on findings from a limited number of studies which suggested that N inputs exceeding these levels were likely to result in elevated concentrations of nitrate-N in drainage from grazed pastoral soils. An important part of this consideration was the recognition that, in most circumstances, the main source of N lost in drainage was from animal urine patches (Silva et al. 1999). Additions of FDE are therefore generally accepted to have an indirect rather than a direct effect on N losses via drainage: greater inputs of FDE-N are cycled through the soil-plant-animal system, resulting in more urinary N deposition and (all other things being equal) consequently more N leaching. Because of this indirect effect of the grazing animal it is important that a grazing systems model (such as the Overseer® Nutrient Budgets model, hereafter referred to as *Overseer*) is employed to determine the likely consequences of adding effluent N to farm blocks. We therefore recommend that an effluent system appraisal should outline the information needs that are required to allow a N loss risk to be determined at both a block (i.e. specifically considering the effluent-treated area) and farm scale.

There is a large body of literature that documents the effects of a range of management practices and mitigation measures for reducing or minimising the risk of N losses to water from grazed dairy farms; for a recent summary, refer to the review by de Klein et al. (2017) and references there-in. These have also been briefly summarised in section 3.2 of the report to Environment Southland by Monaghan (2016) and mostly focus on reducing the accumulation of surplus N in the soil, particularly during autumn and winter.

Table 3. Minimum information requirements for considering contaminant loss risk to water posed by the FDE system.

1	Identification of key contaminant pathways and key contaminants of concern.
2	A nutrient budget showing nutrient inputs from fertilisers, supplements and effluent irrigation and the effect of FDE application on N losses to water, at both farm and block levels.
3	A plan to routinely measure or assess soil temperature and moisture conditions to ensure effluent scheduling decisions are appropriate.
4	An assessment of soil hydraulic and landscape properties for the application area. This should include assessments of soil infiltration rate, slope risk and Plant Available Water (PAW) contents.
5	An assessment of the storage requirement is provided that will allow for appropriate management of effluent.

7. Information Requirements Assessment Template

The information requirements assessment template is a compilation of the minimum information requirements proposed above for the identified key environmental considerations. This is presented below in Table 4.

Table 4. An example assessment template for guiding applicants and consenting staff on the information requirements needed when considering FDE consents and renewals.

Minimum information requirements		Information Supplied (Yes/No)
Maintaining balanced pasture nutrition and soil quality		
1	A nutrient budget has been prepared for effluent-treated areas of the farm.	
2	The budget shows that nutrient inputs from fertilisers and supplements are adjusted to account for nutrient returns in effluent and nutrient surpluses are therefore minimised.	
3	Soil test information is presented (P, K and S in particular) that supports the current plan for nutrient inputs to FDE-treated areas and is consistent with the nutrient budget.	
4	A plan to undertake soil quality evaluations of FDE-treated areas is provided along with descriptions of management actions if pasture nutrition or soil quality problems arise.	
Defining appropriate hydraulic and nutrient loadings		
5	Key contaminant pathways and contaminants of concern have been identified.	
6	A nutrient budget has been prepared showing the effects of FDE application on N losses to water at farm and block levels.	
7	An assessment of soil hydraulic and landscape properties for the application area has been made and used to guide decisions concerning FDE storage, scheduling and method of application.	
8	The FDE system is included and accounted for in the farm plan and nutrient budget.	
9	Relevant good management practices (GMPs) have been incorporated into the proposed system.	

8. Consideration of soil and landscape risk factors within a Southland context

This section attempts to frame the above key considerations within a Southland context, recognising that the proposed Southland Water and Land Plan (pSWLP) sets out some specific requirements for how dairy effluent systems will be assessed in the future. If the farm was lawfully established prior to 3 June 2016, then it may be that only a consent covering the effluent discharge to land is required. If the activity is for a new or expanded dairy farm, then a land use consent may also be required for the broader land use activity in addition to the discharge of effluent to land. The amount and level of information required through a consenting process in Southland is dependent on the type of consents being sought. The pSWLP contains a spatial framework that classifies the region into nine physiographic zones based on water quality risk. The plan has policies specific to each physiographic zone, and the level of information required may vary between zones according to the environmental risk. Table A1 in Appendix 1 documents the key contaminant pathways of concern within each physiographic zone, and each of the Overland Flow and Artificial Drainage variants therein, where they occur. Each of these zones and zone variants was assigned to one of two risk categories that reflected the potential for FDE losses via overland flow, artificial drainage, lateral drainage and/or deep drainage:

- Category NL1: physiographic zones and zone variants assigned to this category were deemed to have a relatively high risk of overland flow, artificial drainage and, for Peat Wetlands, lateral drainage pathways that could potentially rapidly transfer FDE constituents from soil to water. Distinction is made between flat versus sloping (> 7º) land within this category to account for the greater risk of overland flow in the latter.
- Category NL2: due to their relatively well-drained soils and low to moderate slope attributes, physiographic zones and zone variants assigned to this category were deemed to have greater risk of N loss via deep drainage.

Suggested minimum criteria for hydraulic and nutrient loading values for FDE application systems to achieve were then assigned to the NL1 and NL2 categories. A distinction was made within each category to account for contrasting methods of FDE application. As discussed in section 5, low rate sprinkler application systems help to avoid or minimise surface ponding of FDE and ensure applied FDE moves into the soil profile. Compared to more traditional and high-rate methods of FDE application, these low rate systems allow for greater attenuation of effluent contaminants, thus minimising environmental risk. This principle has been extended in recent research published by Laurenson et al (2017) to show how very low FDE application depths can be considered even during times when soil conditions are relatively wet and Soil Water Deficits (SWDs) are close to zero. Required hydraulic loading and FDE scheduling criteria thus differ depending on FDE application method; these attributes are accordingly documented in Tables 5, 6 and 7.

Table 5: FDE hydraulic and nutrient loading minimum criteria for the NL1(flat) risk category. Criteria are grouped according to FDE application method, where low rate and low depth refer to applicators capable of applying FDE at less than 10 mm h^{-1} and 1 mm $application^{-1}$, respectively.

	Traditional applicators	Low rate	Low rate and low depth (LRLD)
Application depth (mm day^{-1})	< SWD*	< SWD	< 2
Max. depth (mm $applic.^{-1}$)	10	25	1
Instant. applic. rate (mm hr^{-1})	N/A**	N/A**	< 4
Average applic. rate (mm hr^{-1})	---------------	< soil infiltration rate	---------------
Storage requirement	Apply only when SWD exists	Apply only when SWD exists	Apply only when rainfall in the preceding 24 h is less than 4 mm and air temp. is > 4°C
Maximum N load:			
kg N $ha^{-1}yr^{-1}$***	150	150	150
kg N $ha^{-1}winter^{-1}$***	0	0	50
Minimum soil temperature (at 10 cm depth)	>6°C	>6°C	>6°C
Minimum air temperature	>4°C	>4°C	>4°C

* SWD = soil water deficit. ** N/A = Not an essential criterion, however level of risk and management is lowered if using low application rates. *** Loading rates specified are a guide only and may not always be appropriate. This will depend on the regulatory and environmental setting.

Table 6: FDE hydraulic and nutrient loading minimum criteria for the NL1(sloping) risk category. Criteria are grouped according to FDE application method, where low rate and low depth refer to applicators capable of applying FDE at less than 10 mm h^{-1} and 1 mm $application^{-1}$, respectively.

	Traditional applicators	Low rate	Low rate and low depth (LRLD)
Application depth (mm day^{-1})	< SWD*	< SWD	< 2
Max. depth (mm $applic.^{-1}$)	10**	10	1
Instant. applic. rate (mm hr^{-1})	---------------	< soil infiltration rate	---------------
Average applic. rate (mm hr^{-1})	---------------	< soil infiltration rate	---------------
Storage requirement	Apply only when SWD exists	Apply only when SWD exists	Apply only when rainfall in the preceding 24 h is less than 4 mm and air temp. is > 4°C
Maximum N load:			
kg N $ha^{-1}yr^{-1}$***	150	150	150
kg N $ha^{-1}winter^{-1}$***	0	0	50
Minimum soil temperature (at 10 cm depth)	>6°C	>6°C	>6°C
Minimum air temperature	>4°C	>4°C	>4°C

* SWD = soil water deficit. ** This method is only applicable where instantaneous application rate < infiltration rate. *** Loading rates specified are a guide only and may not always be appropriate. This will depend on the regulatory and environmental setting.

Table 7: FDE hydraulic and nutrient loading minimum criteria for the NL2 risk category. Criteria are grouped according to FDE application method, where low rate and low depth refer to applicators capable of applying FDE at less than 10 mm h^{-1} and 1 mm $application^{-1}$, respectively.

	Traditional applicators	Low rate	Low rate and low depth (LRLD)
Application depth (mm day^{-1})	< 50% of PAW#	< 50% of PAW#	< 2
Max. depth (mm $applic.^{-1}$)	25** (10 mm at field capacity)	25	1
Instant. applic. rate (mm hr^{-1})	N/A	N/A	< 4
Average applic. rate (mm hr^{-1})	---------------	< soil infiltration rate	---------------
Storage requirement	24 hours drainage post saturation	24 hours drainage post saturation	Apply only when rainfall in the preceding 24 h is less than 4 mm and air temp. is > 4°C
Maximum N load:			
kg N $ha^{-1}yr^{-1}$***	150	150	150
kg N $ha^{-1}winter^{-1}$***	0	0	50
Minimum soil temperature (at 10 cm depth)	>6°C	>6°C	>6°C
Minimum air temperature	>4°C	>4°C	>4°C

#PAW = Plant available water in the top 300 mm of soil; **25 mm is the suggested maximum application depth when a suitable SWD exists (≥ 15 mm).
For very light soils (soils with > 35% stone content in the top 200 mm of soil), FDE application depth should be the lesser of ≤ 10 mm or < 50% of PAW# per day, and ≤ 10 mm per application.
Field capacity should not be exceeded by more than 10 mm using a high rate irrigator.
*** Loading rates specified are a guide only and may not always be appropriate. This will depend on the regulatory and environmental setting.

9. Applying the Assessment Template to the ‘Clean Green’ effluent system in Southland

An example of how this template could be applied to a specific system is presented below in Table 8. The example used is the ‘Clean Green’ effluent system. The system is considered under the policy framework being enacted by Environment Southland.

Table 8. An example assessment protocol for guiding applicants and consenting staff on the information requirements and assessment steps considered within a Southland context. The 'Clean Green' system is used as an example.

	Minimum information requirements	Criteria or comment (Southland specific)
<u>Maintaining balanced pasture nutrition and soil quality</u>		
1	A nutrient budget has been prepared for effluent-treated areas of the farm.	As per requirement under Southland's proposed plan. Use of the Clean Green system in general does not restrict the ability to comply with these criteria.
2	The budget shows that nutrient inputs from fertilisers and supplements are adjusted to account for nutrient returns in effluent and nutrient surpluses are therefore minimised.	The nutrient budget will need to have been prepared following best practice input standards. This is dependent on the individual application.
3	Soil test information is presented (P, K and S in particular) that supports the current plan for nutrient inputs to FDE-treated areas and is consistent with the nutrient budget.	This can be incorporated into the nutrient budget. This is dependent on the individual application.
4	A plan to undertake soil quality evaluations of FDE-treated areas is provided along with descriptions of management actions if pasture nutrition or soil quality problems arise.	Evaluations of soil physical quality can be undertaken following Visual Soil Assessment protocols. This is dependent on the individual application.
<u>Defining appropriate hydraulic and nutrient loadings</u>		
5	Key contaminant pathways and contaminants of concern have been identified.	For Southland, the Physiographic Zones that will receive FDE need to be assessed and key pathways and contaminants of concern identified. These can be identified though utilisation of Southland Physiographic Zone maps or through detailed site investigation. Use of the Clean Green system in general does not restrict the ability to comply with these criteria.

6	A nutrient budget has been prepared showing the effects of FDE application on N losses to water at farm and block levels.	This step provides an assessment of changes in N loss risk (to water). This is dependent on the individual application.
7	An assessment of soil hydraulic and landscape properties for the application area has been made and used to guide decisions concerning FDE storage, scheduling and method of application.	The proposed system will need to be assessed against the identified minimum criteria documented in Tables 5, 6 and 7. This will depend on the specific location of the proposed system. The 'Clean Green' system in general does not restrict the ability to comply with these criteria. The 'Clean Green' system has the ability to meet the minimum criteria set out in Tables 5, 6 and 7. A critical factor will be the calculation of required storage and appropriate nitrogen loading rates. Despite the ability for application at low rates and low depths, there will be a requirement for some storage. The ability for the DESC to calculate the storage requirement for the 'Clean Green' system is currently under review. Storage requirement can be calculated by other means. This may require extra storage to be added to the 'Clean Green' system. Nitrogen loading rates must comply with the appropriate minimum criteria either specified in Tables 5, 6 & 7 or defined through a site-specific process.
8	The FDE system is included and accounted for in the farm plan and nutrient budget.	As per requirement under Southland's proposed plan. This will depend on the individual application; the Clean Green system in general does not restrict the ability to comply with these criteria.
9	Relevant good management practices (GMPs) have been incorporated into the proposed system.	As per requirement under Southland's proposed plan, relevant GMPs are defined for each Physiographic Zone. These will depend on the individual application; the Clean Green system in general does not restrict the ability to comply with these criteria.

10. Acknowledgements

This report was prepared with support from Envirolink Regional Council Advice number: 1904-ESRC288. Guidance and reviews by Ewen Rodway, Karen Wilson and resource consent staff at Environment Southland are gratefully acknowledged.

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12. Appendix 1

Table A1. Key contaminant pathways and contaminants of concern within each of the physiographic zones (and zone variants, where they occur) of Southland. Abbreviations are: OF = overland flow; AD = artificial drainage; LD = lateral drainage; DD = deep drainage; S = sediment; NL = Nutrient Loading.

Physiographic Zone	Variant	Key Contaminant Pathways and Contaminants				High Risk Contaminants	Risk category
		OF	AD	LD	DD		
Alpine		N, P, S, M				N, P, S, FMOs	NA
Bedrock/Hill Country					N	*	NL2
	OF	N, P, S, M				N, P, S, FMOs	NL1 flat or sloping
	AD		N, P, S, M			N, P, S, FMOs	NL1 flat or sloping
Central Plains			N, P, S, M		N	N, P, S, FMOs	NL1 flat or sloping
Gleyed			N, P, S, M			N, P, S, FMOs	NL1 flat or sloping
	OF	N, P, S, M				N, P, S, FMOs	NL1 flat or sloping
Lignite-Marine Terraces						*	NL2
	OF	N, P, S, M				N, P, S, FMOs	NL1 flat or sloping
	AD		N, P, S, M			N, P, S, FMOs	NL1 flat or sloping
Old Mataura					N	N	NL2
Oxidising					N	N	NL2
	OF	N, P, S, M			N	N, P, S, FMOs	NL1 flat or sloping
	AD		N, P, S, M		N	N, P, S, FMOs	NL1 flat or sloping
Peat Wetlands			N, P, S, M	P, M	P	N, P, S, FMOs	NL1 flat or sloping
Riverine					N	N	NL2
	OF	N, P, S, M			N	N, P, S, FMOs	NL1 flat or sloping

* Low risk due to high reduction potential (i.e. denitrification likely to occur)