BEFORE THE HEARINGS PANEL

IN THE MATTER of hearings on submissions concerning the Proposed One Plan notified by the Manawatu-Wanganui Regional Council

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SECTION 42A REPORT OF DR DAVID JOHN HOULBROOKE ON BEHALF OF HORIZONS REGIONAL COUNCIL

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1. INTRODUCTION

My qualifications/experience

1. My name is Dr David John Houlbrooke. I have a Bachelor of Science degree in Earth Sciences and a Master of Science (Hons) degree in Earth Sciences from the University of Waikato. I have a Doctor of Philosophy degree (PhD) in Soil Science from Massey University.

2. I am a serving member of the executive council of the New Zealand Society of Soil Science. I am also a member of the New Zealand Grasslands Association, New Zealand Land Treatment Collective and New Zealand Association of Resource Managers.

3. I am currently employed as a soil scientist working within the Climate, Land & Environment Group at AgResearch, based at Invermay, Mosgiel. I have five years work experience in my current position with AgResearch plus three years with the Western Australian Department of Agriculture as a soil management technical officer. I have a further five years soil science post graduate research experience gained during my MSc and PhD studies.

4. My research experience has focused on soil and water management for intensively farmed agricultural landscapes. My primary research interests focus on the best management practices for the land application of Farm Dairy Effluent (FDE) and the influence and mitigation of animal treading on soil quality and forage production. My research experience particular to FDE management has resulted in 11 scientific papers (five in international peer reviewed journals) and a PhD thesis entitled ‘A study of the quality of artificial drainage under intensive dairy farming and the improved management of FDE using deferred irrigation’. I regularly consult with New Zealand Regional Councils on dairy effluent-related matters and attend and present at dairy industry-related forums.

5. I have read the Environment Court’s practice note, Expert Witnesses – Code of Conduct, and agree to comply with it.

My role in the Proposed One Plan

6. I have provided expertise to Horizons Regional Council on the management of FDE and completed the following report for Horizons in 2008:
   Houlbrooke, D.J. (2008). Best practice management of farm dairy effluent in the Manawatu-Wanganui region. AgResearch client report for Horizons Regional Council.

7. I was also a co-author on the following report prepared by the Sustainable Land Use Research Initiative (SLURI):

Parfitt, R., Dymond, J., Ausseil, A-G., Clothier, B., Deurer, M., Gillingham, A, Gray, R., Houlbrooke, D., Mackay, A., McDowell, R. (2008). Best practice P losses from agricultural land. Landcare Research Contract Report 0708/12.

Scope of evidence

8. The scope of this evidence is to outline existing best management practices (BMPs) for the land application of farm dairy effluent and compare their performance with traditional FDE management practices. The evidence has been prepared in a format to answer a series of questions asked of me by Horizons. The evidence will identify a flow chart/decision tool approach to more readily identify appropriate FDE management practices based on soil and climatic conditions.

2. EXECUTIVE SUMMARY OF EVIDENCE

9. The safe application of farm dairy effluent (FDE) to land has proven to be a challenge for dairy farmers and regulatory authorities throughout New Zealand. Recent research in Manawatu and Otago has identified that poorly performing FDE systems can have large deleterious effects on water quality, particularly when direct losses of FDE containing high concentrations of contaminants (eg. phosphorus, nitrogen and faecal microbes) discharge, drain or run off directly to surface water bodies. In particular, land application of FDE has proven difficult when it has occurred on soils with a high degree of preferential flow, soils with artificial drainage or coarse structure, soils with infiltration or drainage impediments, or when applied to soils on rolling/sloping country. These effects can be exacerbated by climate as high rainfall can further contribute to the poor environmental performance of such land application systems. In the Manawatu-Wanganui Region, such soils are regularly used for intensive livestock production, including dairy farm operations. In comparison, well-drained soils (also farmed in the Region) tend to exhibit matrix rather than preferential flow under drainage, even under soil moisture conditions close to, or at, field capacity. Therefore, they pose a lower risk of direct loss of effluent contaminants.

10. To decrease or prevent the contamination of fresh water bodies with raw or partially-treated FDE, and better utilise the nutrient resource within dairy effluent, some best management practices (BMPs) have been developed and tested to improve the management of FDE in New Zealand. The concept of ‘deferred irrigation’ has demonstrated that if FDE is stored in a suitably sized and lined pond when soil moisture

is close to, or at, field capacity, and then applied to land at a time when appropriate soil moisture deficits exist, direct drainage or run-off of applied FDE can virtually be eliminated. Furthermore, the high application rate of travelling irrigators has been found to be difficult to manage for soils on sloping terrain, and on soils with either infiltration or drainage limitations or preferential flow characteristics. Low application rate methods allow for greater control of application depth as well as better matching of the soil's ability to infiltrate and absorb applied FDE, thereby improving the likelihood of storing the valuable nutrients within the plant root zone.

11. The applicability and effectiveness of the existing best management practices of 'deferred irrigation' and 'low application rate tools' varies with climate and soil type. Horizons' Region has many soil types with critical limitations in combination with relatively high natural rainfall (>1,000 mm/yr). To gain the best use of effluent nutrients and decrease environmental risk, FDE should be applied in a manner that keeps it in the root zone. To achieve this, movement of water associated with FDE needs to be predominantly in the form of matrix flow (through and around small peds [soil structure units] and pore spaces) to increase soil attenuation of applied FDE. Soils with critical limitations will require the application of BMPs in order to minimise preferential flow and keep applied FDE contaminants in the root zone. However, the effectiveness of the BMPs will be considerably less on soils without critical infiltration and drainage limitations, as they already exhibit matrix flow under relatively wet soil moisture conditions.

12. Farm dairy effluent is a very important source of nutrients (and water). Cattle spend approximately 10% of their time each day at the milking shed or in the dairy yards for which all excretions are collected. Using the OVERSEER® nutrient budgets programme and autumn 2009 fertiliser prices, it is estimated that FDE provides a nutrient value of approx $33.50/cow for a 225 ha property stocked at 3.2 cows/ha on a fully pasture grazed system. If the system is intensified to a stocking rate of 4.0 cows/ha by bringing in supplementary feed, then the estimated nutrient value is approximately $160/cow, largely because of the considerable K content of imported feed.

13. I recommend that Horizons require that farm dairy effluent management practices are matched with soil and landscape features, in order to prevent direct losses of effluent contaminants following the land application of FDE. A decision tool has been constructed to guide appropriate effluent management practice. This tool is outlined in Table 1, and identifies the minimum criteria that a FDE land application system should meet. Table 2 recommends application criteria and provides a guide for storage

requirements based on soil and landform features (Table 1). Where critical climate, landform and soil characteristics apply, BMPs will help mitigate or prevent the direct loss of contaminants from FDE applied to land.

Table 1. Suggested minimum criteria for a land-applied effluent management system to achieve

Soil and landscape feature	Artificial drainage or coarse soil structure	Impeded drainage or low infiltration rate	Sloping land (>8°)	Well drained flat land (<8°)
Application depth (mm)	< SWD*	< SWD	< SWD	< 50% of WHC#
Application rate (mm/hr)	N/A	N/A	< soil infiltration rate	N/A
Storage requirement	Apply only when SWD exists	Apply only when SWD exists	Apply only when SWD exists	Avoid application during rainfall
Maximum N load	150 kg N/ha/yr	150 kg N/ha/yr	150 kg N/ha/yr	150 kg N/ha/yr

* SWD = soil water deficit [#] WHC = water holding capacity

Table 2. Revised decision tool for matching FDE management practice with soil and landscape features. The storage guidelines are based on soils with an annual rainfall <1,100 mm.

Soil and landscape feature	Artificial drainage or coarse soil structure		Impeded drainage or low infiltration rate		Sloping land (>8°)			Well drained flat land (<8°)	
Infiltration rate	N/A		N/A		< 100 mm/hr	> 100 mm/hr		N/A	
Irrigator hardware	LR[XX]	TI[#]	LR	TI	LR	LR	TI	LR	TI
Minimum SWD* (mm)	8	15	8	15	8	8	15	0	0
Storage guide (weeks)	8	12	8	12	8	8	12	1 day	3 days

[#] TI = Travelling irrigator, [XX] LR = low rate irrigator, * SWD = soil water deficit

3. EVIDENCE

What is best management practice for farm dairy effluent?

14. A sustainable land treatment system must be efficient in both the retention of effluent in the soil and the subsequent plant uptake of nutrients applied in the effluent. The longer the effluent resides in the soil’s active root zone, the greater the opportunity for the soil to physically filter the effluent whilst attenuating potential contaminants and making the nutrients available to plants. Houlbrooke (2008) provides a summary of best management practices for land application of FDE prepared for Horizons Regional Council. This document summarises much of the published research on effluent management carried out by myself and my former colleagues at Massey University (in particular Dr Dave Horne, Dr Mike Hedley and Mr James Hanly) and my AgResearch colleague Dr Ross Monaghan. Extracts from this report are summarised in much of the evidence below.

Deferred Irrigation

15. To help overcome the problems associated with the spray irrigation of FDE to artificially drained soils and soils with drainage limitations, an improved treatment system called ‘deferred irrigation’ has been developed. The concept of deferred irrigation was designed and evaluated at the Massey University No.4 Dairy farm near Palmerston North. Deferred irrigation involves storing effluent in a pond then irrigating it strategically when there is a suitable soil water deficit, thus avoiding the risk of surface run-off or direct drainage of effluent. When applied effluent adds to the volume of plant available water (rather than drainage water), the soil-plant system’s ability to remove soluble nutrients via plant uptake and immobilisation processes is maximised.

16. The application criteria for spray irrigation of FDE, if drainage is to be avoided, are presented in the following equations:

$$E_i + \theta_i Z_R \leq \theta_{FC} Z_R \qquad \text{e.q. 1}$$

$$E_i \leq Z_R\,(\theta_{FC} - \theta_i) \qquad \text{e.q. 2}$$

Where E_i is the depth of FDE (mm) applied on day i, $Z_{R,}$ is the effective rooting depth (mm), q_{FC} is the soil water content at field capacity ($m^3\ m^{-3}$), and q_i is the soil water content on day i ($m^3\ m^{-3}$) (Houlbrooke *et al*., 2004a). Both of these equations effectively state that the existing soil moisture deficit in the root zone plus the depth of applied FDE, is required to be less than maximum soil water storage (field capacity) if FDE is to be safely applied.

17. In Manawatu, regular soil water deficits greater than 10 mm mainly occur between the months of October and May. However, the generation of FDE starts at the beginning of lactation in late winter (late July/August). Consequently, having sufficient storage for FDE is essential to ensure that spray irrigation to soils with an inherent risk only occurs during times when an adequate soil water deficit exists. While storage is the most important infrastructural requirement, the accurate scheduling of FDE to coincide with soil moisture deficits is also critical.

18. Soil water deficits can either be modelled using a water balance approach or measured on a volumetric basis in the field. A number of different tools exist to provide actual soil moisture data. An on-farm soil moisture tape is an excellent means of recording soil moisture and plotting trends over time. The compromise is that the soil moisture reading relates directly to the paddock that it sits in; therefore the paddock's place in the FDE block rotation needs to be accounted for, as do any differences in application depth between paddocks. The alternative is the use of a handheld soil moisture meter, such as a TDR probe. The advantage of such a system is that it can readily be carried around the property, providing soil moisture data on a paddock-by-paddock basis. The disadvantage is that this data is often not electronically recorded and so good soil moisture records are difficult to establish. Further options to assess soil moisture contents are to observe regional soil moisture data (not farm-specific) or employ the services of an irrigation consultant to measure soil moisture throughout the irrigation season. However, with some commonsense approaches and self calibration, judicious operators should be able to determine when adequate water deficits occur, based on visual assessment of the soil and time since the last rainfall event.

Irrigator hardware

19. A range of different irrigators is available in New Zealand for applying FDE to land. The most common option is the rotating twin boom travelling irrigator (Plate 1a). More recent options on the market include an oscillating travelling irrigator called Spitfire (Plate 1b), and low rate applicators such as K-Line (Plate 1c) and Larall (Plate 1d).

20. The depth of applied FDE has important implications for determining the likelihood of ponding, surface run-off and drainage, depending on the drainage characteristic of the soil. Here, I use the term application depth as the mean depth (mm) of FDE applied under the footprint of an irrigator for a given application. For soils with an inherent risk, it is important that the application depth applied to a soil is less than the soil water deficit available at the time. When only very small soil water deficits are available (ie. <10 mm)

the twin boom travelling irrigators struggle to apply depths less than this deficit (Figure 1). When soil water deficits are low (<20 mm) it is important to run travelling irrigators at their fastest travel speed, to provide their lowest application depth.

21. Low rate applicators are temporarily fixed in one place and have application rates of approximately 4 mm per hour. Therefore, a one-hour application would add only 4 mm of FDE to the soil. Low depth applications allow for FDE to be applied in smaller amounts, more often during periods of low soil moisture deficit (<10 mm).

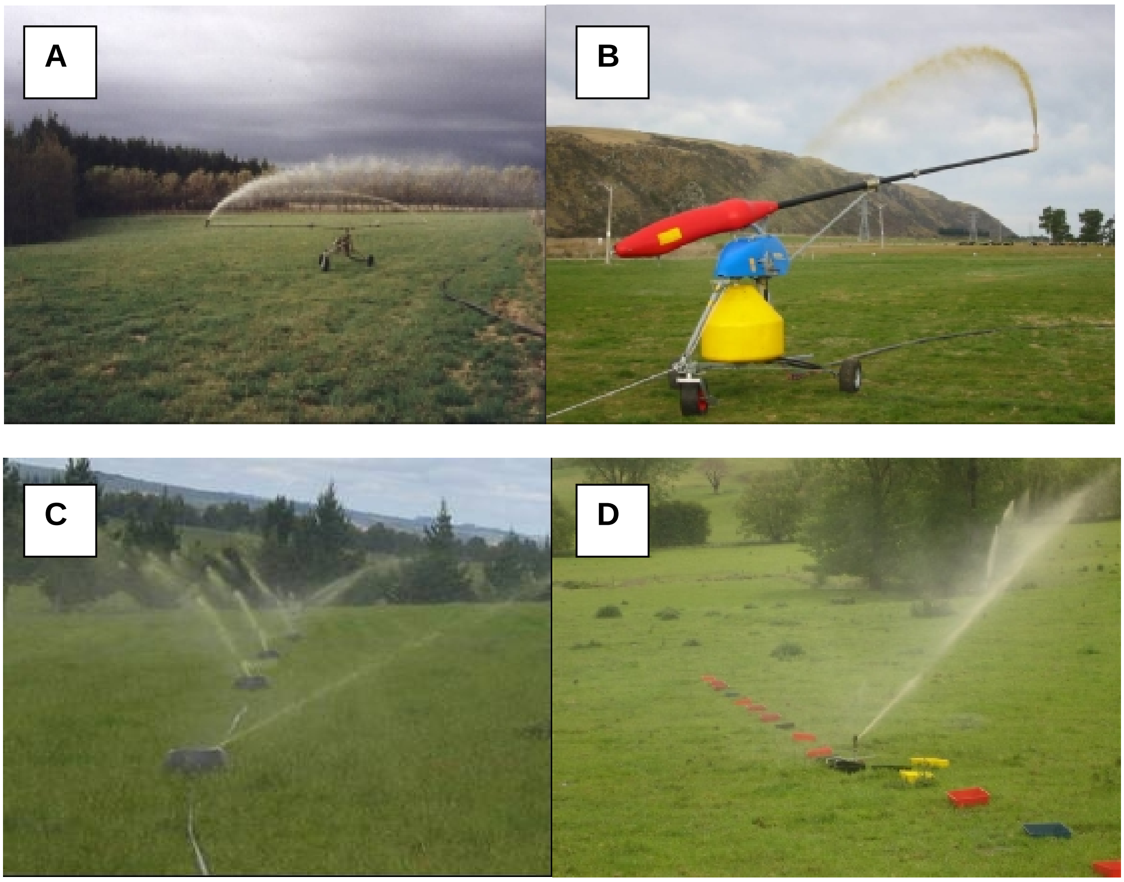

Plate 1. A: Rotating twin boom irrigator; B: Oscillating Spitfire irrigator; C: Low application rate K-Line irrigation pods; D: Low application rate Larall One irrigation pod.

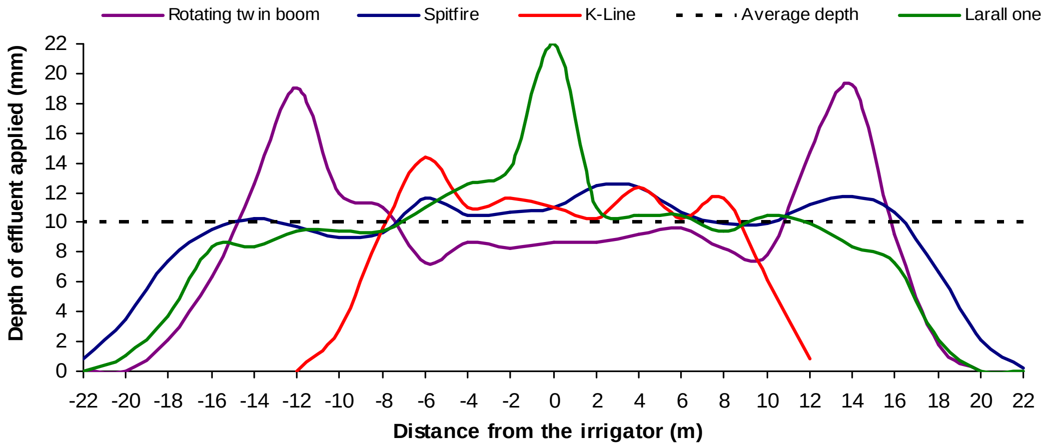

Figure 1. Example of typical application depths and uniformities of a range of different tools available for irrigation of FDE in New Zealand.

22. The application rate of an irrigator has a strong influence on environmental performance for soils that exhibit a high degree of preferential flow, a drainage limitation, or are situated on sloping land. Soils have differing infiltration rates and abilities to absorb and drain water. For example, coarse textured soils have a greater infiltration rate than fine textured soils. FDE application rates should be matched to a soil type's ability to absorb or infiltrate effluent. Travelling irrigators have very high instantaneous application rates, typically greater than 100 mm/hr. However, due to the doughnut application pattern, not all ground under a travelling irrigator continuously receives effluent as an irrigator pass is being made, meaning the average application rate is more like 20 mm/hr. Low-rate applicators usually apply FDE at rates of only 4 mm/hr or less. This reduces the risk of exceeding a soil's infiltration capacity, thus minimising ponding and surface run-off of freshly applied FDE. Furthermore, the lower application rates increase the retention of applied nutrients in the root zone. Low application rate reduces transport through preferential flow paths and allows greater movement through smaller soil pores via matrix flow, thus allowing for greater attenuation of effluent contaminants

Matching FDE management practice to soil and landscape features using the original flow chart

23. The applicability and effectiveness of existing BMPs (deferred irrigation and low application rate tools) varies with climate and soil type. Horizons' Region contains soil types with infiltration and/or drainage limitations in combination with relatively high natural rainfall (>1,000 mm/yr). To gain the best use of effluent nutrients and reduce environmental risk, FDE should be applied in a manner that keeps it in the root zone. To

achieve this, movement of water associated with FDE needs to be predominantly in the form of matrix flow (through and around small peds and pore spaces) to increase soil attenuation of applied FDE. Soils that exhibit a high degree of preferential flow (also known as bypass flow) will require the provision of soil water deficits and/or a lower application rate of FDE in order to reduce the risk of preferential flow. Some different soil type and farming system scenarios are discussed below with regard to their applicability, effectiveness and, therefore, need for best practice FDE management. A report on the influence of soil drainage characteristics on contaminant leakage risk associated with land application of FDE has been produced by AgResearch Ltd for Environment Southland (Houlbrooke and Monaghan, 2009) and provides more detail than the summary below.

Mole-pipe drained land

24. In Horizons' Region, dairy farming can occur on poorly or imperfectly drained soils. To farm these fine-textured soils in an intensive manner, artificial drainage systems are often required to alleviate regular winter and spring water-logging (Figure 2). These poorly and imperfectly drained soils are commonly of the Pallic and Gley soil orders as described in the New Zealand Soil Classification. Such soil types are particularly common on the loess-covered terraces of Manawatu.

25. The application of FDE to mole and pipe-drained land has proven difficult to manage because of the preferential drainage pathways for the rapid movement of irrigated FDE (Plate 2). Soils that exhibit a high degree of preferential flow pose a large risk of direct losses of effluent contaminants associated with the land application of FDE. The risk of direct loss of FDE contaminants is particularly high in early spring when soil is often close to, or at, field capacity. The provision of suitable effluent storage for periods when soils are wet, and a method for accurately determining soil moisture contents, would allow for FDE application to be scheduled in a deferred irrigation manner, thus minimising or preventing the likelihood of direct contaminant losses of raw or partially-treated FDE entering waterways via the pipe-drain network.

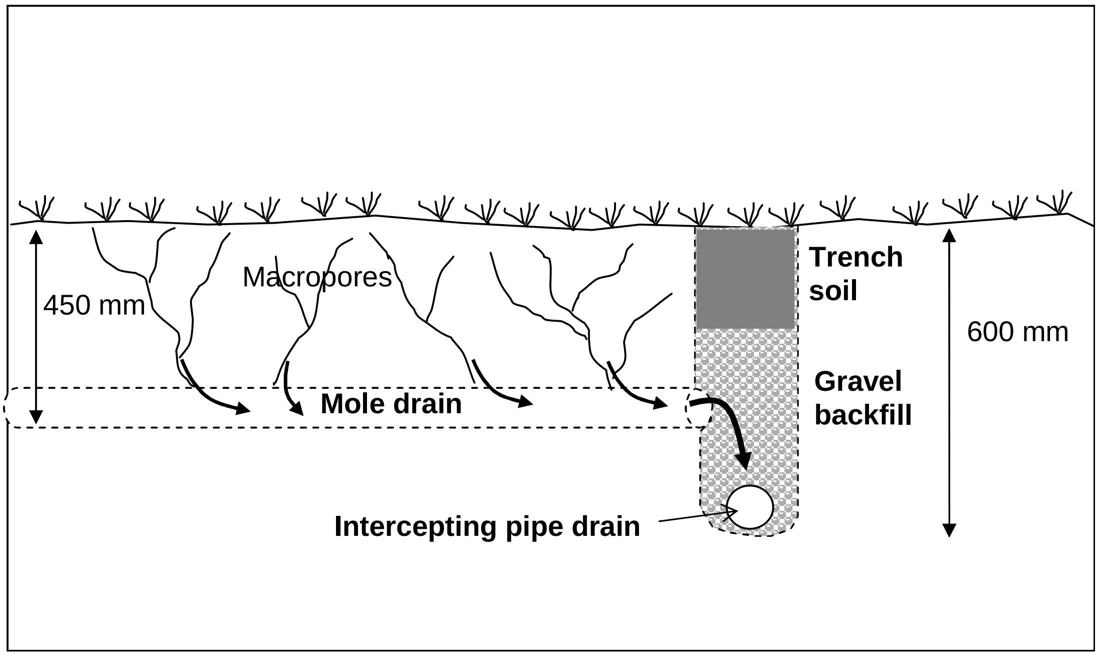

Figure 2. Diagrammatic representation of a mole-pipe drained soil.

26. Direct drainage of irrigated FDE is related to soil water deficits and the high instantaneous rate of application. High application rate travelling irrigators can increase preferential flow through the large macropore network above the mole channels. Some preferential flow can occur, whether there is a suitable deficit or not, particularly if travelling irrigators are not applying at their fastest ground-speed setting (ie. >10 mm depth). In contrast, low application rate tools provide a high degree of flexibility of control of application depth, while the lower rate encourages increased transmission of water through micropores. The combination of low rate tools with deferred irrigation offers much potential for preventing direct drainage losses of contaminants following irrigation of FDE to mole and pipe-drained land. Examples of dairy-farmed mole and pipe drained soils include Pallic soils such as the Tokomaru, Marton and Milson silt loams, situated on the uplifted marine terraces associated with the Manawatu, Rangitikei and Oroua rivers.

Plate 2. Evidence of preferential flow around mole channels in a Tokomaru silt loam.

Soils with low infiltration rates and sloping land

27. In some circumstances, intensive dairy farm operations in Horizons' Region are located on rolling country (c.>8°) with low surface infiltration. These soils also typically belong to the Pallic soil order, characterised by high density, slowly permeable subsurface horizons, often over a fragipan which has highly restricted permeability when wet. The low infiltration rates of many of these soils, in combination with sloping land, pose a high risk of surface ponding and subsequent overland flow when FDE is applied using high application rate travelling irrigators. Low-rate irrigation tools have application rates more suitable for these soil types and thus allow for soil infiltration and hence storage and subsequent filtration of contaminants in the applied FDE. For a number of practical and environmental reasons, it is recommended that such systems are also run in accordance with deferred irrigation.

Soils with impeded drainage or low infiltration rate

28. Some dairy farming in the Region takes place on flat or undulating land with relatively severe drainage limitation. The limitation is usually a result of a regular shallow water table during the winter-spring period. Impeded drainage at depth is a key soil feature identified as increasing the likelihood of overland flow and preferential flow through large soil pores. Intensive dairy farming on these soils usually requires artificial drainage, and

therefore poses an increased risk of contamination of surface drainage waters resulting from poorly timed applications of FDE. Examples of such soil types are Kairanga series (alluvial parent material, Gley soil order) on the Manawatu River plains and the Opiki peat soils (Organic soil order) in the lower Manawatu plains. The provision of adequate FDE storage and a deferred irrigation approach for the scheduling of FDE application to these soils would minimise the chance of contaminating the installed drainage system with raw or partially-treated FDE. There would also be a further benefit from applying FDE with low application rate tools. With respect to the Kairanga soil series, the texture can range from fine sandy loam to a heavy silt loam. Where the soil texture is a silt loam or finer, there is also a likelihood of slow infiltration and passage of water.

Well drained soils

29. Well drained soils, with little or no connection to surface water, will benefit least from adopting best practice effluent management. Well drained soils are typically characterised by high surface infiltration rates and a large degree of matrix flow and would therefore have the least to gain from applying FDE with low application rate tools. Travelling irrigators should be adequate for land applying FDE under these circumstances. Examples of such soils are the well drained, alluvial Manawatu silt loam or fine sandy loam, and the stonier Ashhurst stony silt loam on the Manawatu plains. The well drained soils developed on the rolling sand country in the western Manawatu, such as the Foxton sandy loam, are another relevant category, so long as there is no drainage impediment associated with a shallow water table.

30. Well drained soils have typically high infiltration rates combined with predominantly matrix flow, therefore direct losses of FDE are unlikely even during periods of low soil water deficit. Matrix flow is often called a piston flow effect, where soil surface inputs displace and drain water situated deeper in the soil profile, thus allowing applied FDE a suitable residence time to attenuate potential contaminants. Direct drainage losses are only likely at soil saturation (0 KPa), when all soils exhibit a greater degree of preferential flow, or if application depth exceeds the soil's water holding capacity. In reality, well drained soils will struggle to reach a true state of saturation. However, the combination of prolonged heavy rainfall and application of FDE (particularly large depths) may be enough to temporarily induce saturation conditions. Therefore, it is recommended that a small amount of storage (approximately 2-3 days) combined with a strategy of low application depth (irrigator set at fastest travel speed) would be sufficient to avoid any direct losses of FDE during conditions of low soil water deficit (ie. close to field capacity). Some operators may still wish to include a longer component of FDE

storage, in order to remove all risk associated with applying FDE to wet soil and in order to rationalise staffing issues and prioritise during the traditionally busy and wet calving period. In summary, where there are few hydrological pathways directly connecting soils to water bodies, then the current widespread practice of daily application using a high application rate travelling irrigator is unlikely to cause environmental effects.

31. With little or no likely direct drainage contribution, the extent of, and impact from, contaminants added as FDE to well drained soils that leach to groundwater should be kept in context. As FDE accounts for approximately 10% of the daily nutrient load from cattle excreta, nutrient loading from excreta deposited in the field is the main contributor. Furthermore, the nutrient loads into groundwater differ from that which left the root zone, and will reflect the length of time for further filtration (depth to water table) and any denitrification that may take place throughout the vadose zone (the unsaturated zone between the top of the ground surface and the water table). Well drained soils are often characterised by high nitrate-N losses. However, FDE contributes only a component of the total N inputs that are mineralised into nitrate-nitrogen and subsequently leached from the root-zone. Mitigation techniques for N loss on these well drained soils should target the cumulative effects of urine patches deposited during animal grazing in autumn. (Please refer to the evidence of my colleague Dr Ross Monaghan with regards to effective options for mitigating N loss for intensive dairy grazed pastures).

32. The flow charts presented below (Figures 3, 4, 5) were a first attempt by Houlbrooke (2008) at creating a decision tool to guide BMPs for FDE application to land, based on a soil's inherent risk for direct contaminant losses. The flow charts also recommended different pond storage requirements, taking into account the irrigator hardware used. It is important to note that the above listed storage requirements for differing climatic and landform conditions were considered a 'rule of thumb' assessment. Exact storage requirements should be calculated on a site-specific basis and the methodology for doing this is discussed below in section 49. Storage recommendations for the original freely drained soil flow chart were made assuming a cautious approach, to ensure FDE was not applied to wet soil and also to capture the benefits associated with labour rationalisation during the busy and wet spring period on a farm when calving takes place. Therefore, storage guidelines for the free draining flow chart do not reflect minimum recommendations on an effects basis.

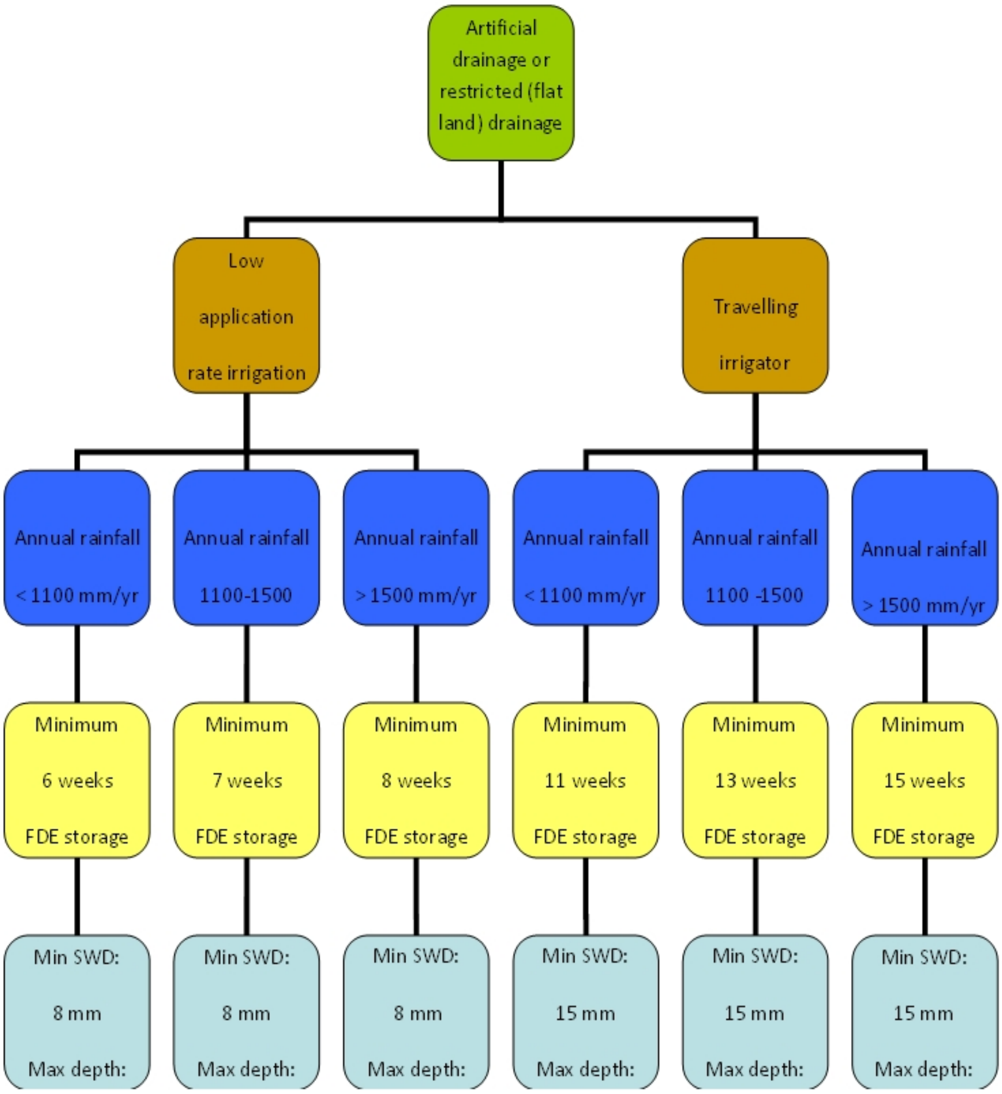

Figure 3. Original flow chart to guide proposed Best Management Practice (BMP) for land application of FDE on artificially drained soils and soils with drainage limitations.

Figure 4. Original flow chart to guide proposed BMP for land application of FDE on sloping land.

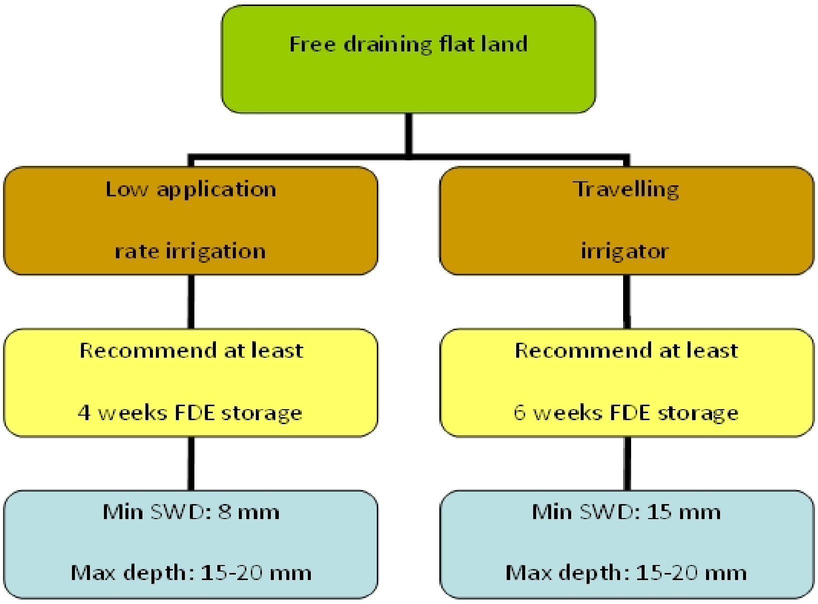

Figure 5. Original flow chart to guide proposed BMP for land application of FDE on free draining flat land

What advantage does Farm Dairy Effluent (FDE) best practice bring?

33. A literature review of New Zealand data (cited in Houlbrooke, 2008) on applying FDE to land, and its effects on water quality, has shown that between 2-20% of both the nitrogen (N) and phosphorus (P) applied in FDE is either lost as run-off or leached from the soil profile. Losses of FDE can be measured in the direct drainage of untreated or partially-treated effluent immediately following irrigation events, and/or in the indirect drainage that occurs in the following winter/spring period. Indirect losses of nutrients associated with land application of FDE are the result of nutrient enrichment of the soil during the summer-autumn period, followed by leaching during the subsequent winter-spring drainage period. Indirect drainage losses therefore reflect a soil's fertility level and cannot be managed using effluent application BMPs. The direct losses of FDE reported below have been summarised previously in Houlbrooke (2008) and Houlbrooke and Monaghan (2009).

Dairy effluent best practice returns nutrients (and water) to where they are needed and keeps contaminants out of the water.

Research summary

34. Direct losses of FDE occur when effluent is applied to soils that: 1) have a limited capacity to store the applied moisture and a propensity for preferential flow (thus resulting in drainage or 'saturation excess' overland flow); or 2) occur on sloping land where the risk of 'infiltration excess' overland flow is high.

35. Research on the Massey University No 4. Dairy farm demonstrated the considerable size of direct losses of nutrients when applying FDE to soils with limited soil water deficit. The soil was a naturally poorly drained Tokomaru silt loam (Fragic Pallic) with mole and pipe drainage installed. When 25 mm of FDE was applied to this soil at near field capacity (6 mm deficit), approximately 40% of the applied effluent left the soil profile as mole and pipe drainage and 30% as surface run-off. The concentrations of N and P in the mole and pipe drainage were approximately 50% of the concentrations applied in the FDE. The impact of this one-off event on N and P loss can be seen in Figure 6, which compares the measured annual loss under dairy farming (including deferred irrigation of FDE) with that experienced from the one poorly managed event. The relative concentration of N and P in surface run-off was approximately 80% of that in the raw FDE. The greater concentration of nutrients in surface run-off reflects minimal interaction between soil and FDE. Total losses from artificial drainage and surface run-off equated to 12 kg N ha^{-1} and 2 kg P ha^{-1}. These nutrient losses from a single, badly-managed irrigation event are significant, particularly when compared to annual farm drainage losses of around 31 kg N ha^{-1}, and less than 0.7 kg P ha^{-1} from pastures grazed by dairy cattle with effluent irrigation operated using deferred irrigation criteria. In other words, N losses from a single FDE irrigation event to wet soil equated to about 40% of the expected annual N drainage loss from grazed dairy pasture, while P losses were equivalent to more than twice the expected annual drainage loss from a grazed dairy pasture.

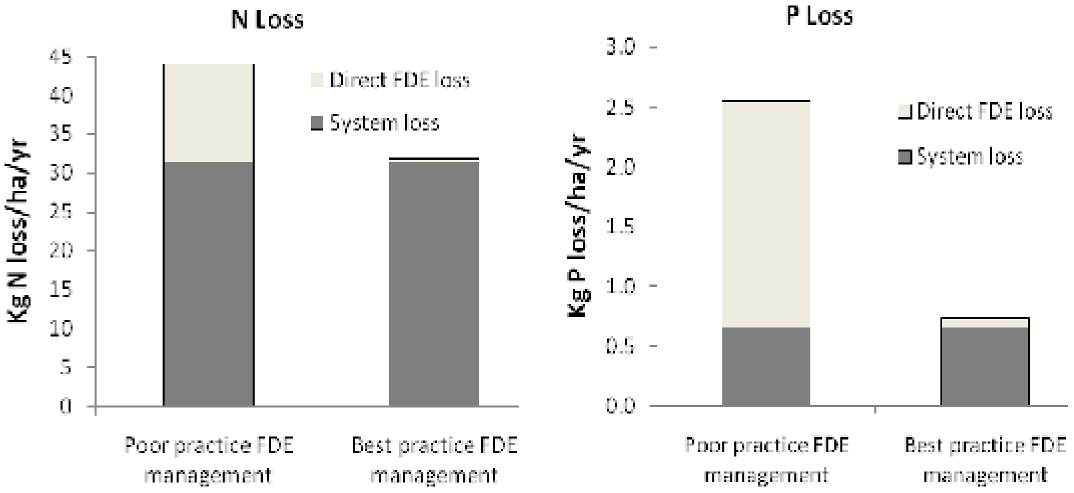

Figure 6. Nutrient loss under dairy landuse in an effluent block comparing poor practice (one poorly timed event) vs. good practice (deferred irrigation criteria).

36. When averaged over three lactation seasons (2000-01 to 2002-03), FDE application to a mole and pipe-drained soil at Massey University generated drainage equivalent to 1.1% of the total effluent applied using the deferred irrigation criteria. A range of different application depths were assessed over the three seasons. The 2001-02 season was wetter than usual with smaller summer deficits available; 63 mm of effluent was therefore applied over seven events at an average of 9 mm depth per application. The strategy of irrigating smaller quantities of FDE, more frequently, resulted in zero drainage of applied effluent through the mole and pipe-drainage system and, consequently, no direct loss of nutrients. Average annual nutrient losses from direct drainage of FDE following irrigations using the deferred irrigation criteria over three lactation seasons were c. 1.1 kg N ha^{-1} and 0.2 kg P ha^{-1}. Similar environmental performance has also been reported in the Otago region when FDE was stored and applied when appropriate soil water deficits developed. This shows that an improved FDE land application system, such as a deferred irrigation strategy, can minimise the environmental risk associated with a daily application system. However, if insufficient storage is available to fully implement deferred irrigation practice, then FDE irrigations should be made using low application rate tools and at low depths, to minimise the potential for direct drainage losses. Where low-rate tools are not available, travelling irrigators should apply FDE at the lowest depths possible to reduce the risk of FDE drainage and run-off.

37. Low-rate effluent irrigation technology in the form of a K-Line system has been evaluated as a tool for applying FDE to land, and its environmental performance has

been compared with that of a traditional rotating travelling irrigator. Two research sites were used, in west and south Otago. Both were on the poorly drained and structured Pallic soil (the Waikoikoi silt loam), which is similar in nature to Manawatu Pallic soil types such as the Tokomaru silt loam. The west Otago site was mole and pipe drained. Drainage monitoring showed that concentrations of contaminants in artificial drainage were much reduced when a low-rate applicator was used. Specifically, much of the P, ammonium-N and *E. coli* bacteria contained in the FDE was filtered by the soil when FDE was applied using low-rate technology. Concentrations of total P, ammonium N and *E. coli* measured in drainage induced by the application of the FDE without intermittent pumping were, on average, only 5%, 2% and 25% of that found in the applied FDE, respectively (Figure 7). These values were further decreased by adopting an intermittent pumping regime of 12 minutes on followed by 48 minutes off. This was in contrast to that observed when FDE was applied using a rotating travelling irrigator (mean application depth of 9 mm), where concentrations of total P, ammonium N and *E. coli* measured in drainage induced by the application of the FDE were 33%, 30% and 85% of that found in the applied effluent.

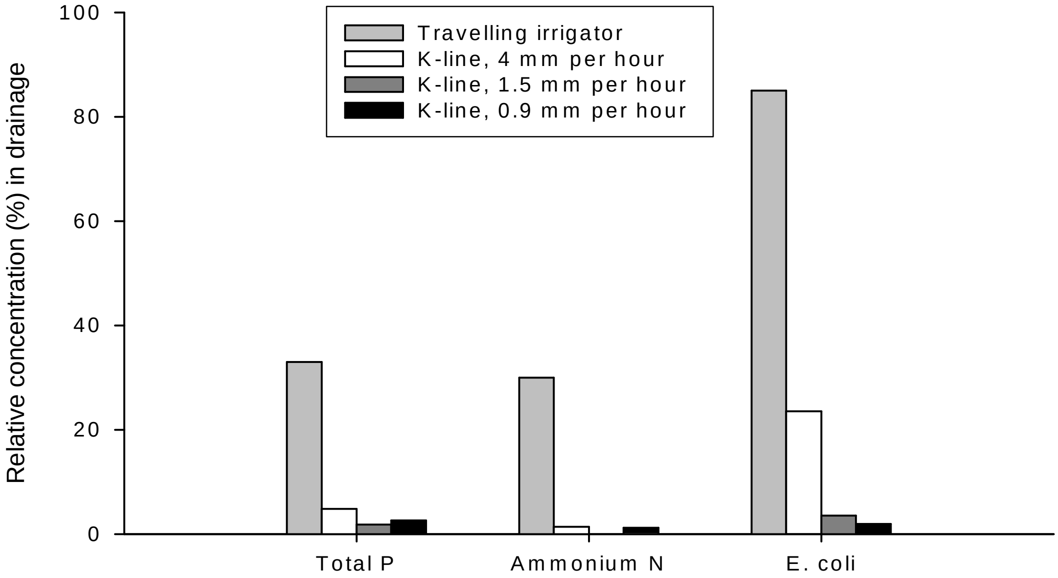

Figure 7. Relative concentrations of total P, ammonium N and *E. coli* in drainage waters collected following the irrigation of FDE to a mole-pipe drained soil using a travelling irrigator or K-line irrigation system. Concentrations are expressed as a percentage of those measured in the applied FDE.

38. The south Otago site was on sloping land with poor surface infiltration. Applications of FDE made at this site under similar moisture conditions resulted in 78% of the volume of FDE applied using a rotating travelling irrigator being generated as overland flow, compared to 44% when using low-rate (K-Line) irrigation. As for the mole and pipe drainage research site, there was also an attenuation effect for the low-rate application method. The relative concentrations of contaminants in overland flow generated following the application of FDE using a low-rate system were considerably lower (between 20-45%) than observed for the high-rate travelling irrigator. The success of low-rate irrigation tools on sloping land, and land with artificial drainage, is attributed to the greater filtration of nutrients and faecal bacteria in the FDE, compared to that achieved under the high instantaneous rate of application observed under a rotating travelling irrigator. The low application rate and associated decrease in surface ponding of FDE allows a greater volume of applied FDE to move through smaller soil pores via matrix flow, thus allowing for greater attenuation of effluent contaminants.

39. A summary of research investigating the potential for microbial contamination of drainage water following FDE application has been published by McLeod *et al*. (2008), to develop risk categories for exhibition of preferential flow across a large range of New Zealand soil types. The standard experimental procedure was to apply 25 mm of FDE, followed by the equivalent of one pore volume of rainfall at a rate of 5 mm/hr. Soil orders and specific soil characteristics were classified as having low, medium or high risk of preferential flow, following interpretation of drainage breakthrough curves. A schematic example of a breakthrough curve demonstrating preferential and matrix flow conditions is presented in Figure 8.

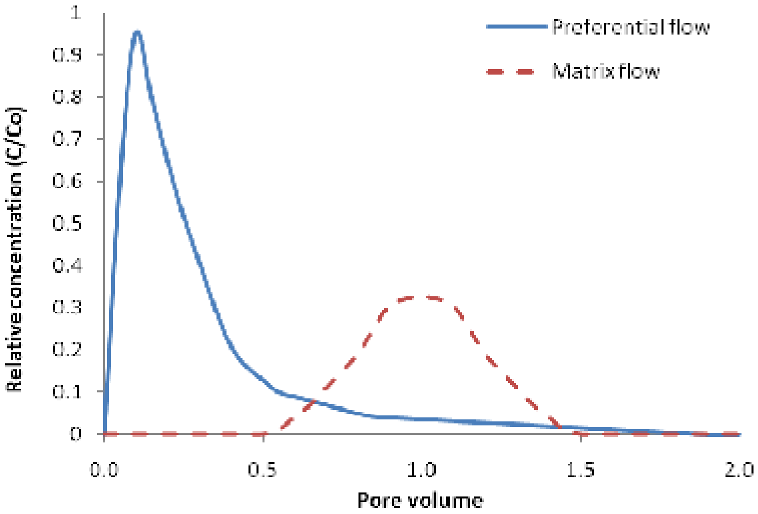

Figure 8. Illustration of typical breakthrough curves for preferential vs. matrix flow (Houlbrooke and Monaghan 2009).

40. The following soil characteristics or soil orders/subgroups in the New Zealand Soil Classification were identified as having a high preferential flow risk *(McLeod et al., 2008)*:

- Organic soils
- Ultic soils
- Granular soils
- Melanic soils
- Podzol soils
- Gley and Perch-gley soils
- mottled subsoils
- peaty soils
- skeletal soils
- soils with a slowly permeable layer
- soils with coarse soil structure
- soils with a high K_{SAT}:K_{-40} ratio

41. The following soil characteristics or soil orders in the New Zealand Soil Classification were identified as having a medium preferential flow risk *(McLeod et al., 2008)*:

- Brown soils
- Pallic soils
- Oxidic soils

42. The following soil characteristics or soil orders in the New Zealand Soil Classification were identified as having a low preferential flow risk *(McLeod et al., 2008)*:

- Allophanic soils
- Semiarid soils
- Pumice soils
- Recent soils

The four soil orders described as having low preferential flow risk are all characterised by well drained soil profiles.

43. While there has been considerable research specifically investigating the potential for microbial contamination in well drained soils, there has been little research established to identify the risk of direct drainage losses of nutrients applied in FDE in soil characterised by well drained soil profiles. However, a number of studies conducted by Lincoln University in the Canterbury region on well drained soils have compared the addition of different N inputs on total N leaching losses. These research studies have compared FDE with fertiliser and excreta inputs, and in all circumstances FDE has contributed only to indirect losses of N leached. Breakthrough curves presented suggest

little or no preferential flow for these well drained soils. A further summary of the research conducted at Lincoln University can be found in Houlbrooke and Monaghan (2009).

Simulation assessment

44. An assessment of the environmental performance of a range of FDE management practices has been made using the OVERSEER® nutrient budgets model version 5.4.3 (hereafter referred to as OVERSEER) on two different soil types. OVERSEER captures the effect of effluent management practices on P loss as drainage and/or surface run-off. Losses of N are not able to be assessed in a similar manner as the OVERSEER model does not allow for direct (non-nitrate) N losses in drainage/run-off. The assessments were established with the following conditions:

- Fixed rate of N inputs as either FDE or fertiliser (150 kg N/ha);
- Olsen P of 42 on FDE block and rest of platform;
- P inputs (as FDE and fertiliser) set as maintenance for stated Olsen P;
- Poorly drained soil = Tokomaru silt loam (Fragic Pallic soil, NZSC);
- Well drained = Ashhurst stony silt loam (Orthic Brown soil , NZSC);
- Platform = 164 ha, FDE block = 36 ha (c. 6.5 ha/100 cows);
- Stocking rate = 2.8 cows/ha;
- Milksolids = 1,220 kg/ha/yr.

45. The poorly drained Tokomaru silt loam is a mole- and pipe- drained soil found extensively in the Manawatu region. It is typical of flat to undulating loess-covered terrace soils found in the Manawatu. The Ashhurst stony silt loam is a shallow well drained soil overlying coarse textured sub-soils. The Ashhurst soilIt is situated in low alluvial river terraces of the Manawatu River and is typical of many New Zealand well drained alluvial river terrace soils. Five different effluent management scenarios have been were evaluated over the two different soil types in order to test the influence and inherent risk of soil and landscape features on the effectiveness of FDE Bbest mManagement pPractices (BMPs):

- Sump slow = Daily application using a travelling irrigator set with high depth per application (> 24 mm).
- Sump fast = Daily application using a travelling irrigator set with lowest depth per application (< 12 mm).
- Sump low rate = Daily application using a low application rate irrigator
- Storage fast = Pond storage and deferred irrigation using a travelling irrigator set with lowest depth per application (<12 mm).

- Storage low rate = Pond storage and deferred irrigation using a low application rate irrigator.

46. Effluent management practice had a considerable influence on the percentage whole-farm P loss derived from FDE (Figure 9). Daily application using a travelling irrigator at slow speed on a mole and pipe-drained soil contributed to nearly 60% of whole-farm P losses, at a rate of nearly 7 kg P/ha/yr on the FDE block (Figure 10). Increasing the speed of the irrigator decreased reduced this loss to 35% of farm loss, at a rate of 2.7 kg P/ha/yr from the FDE block. Implementing deferred irrigation was predicted to decrease the direct loss of P down to 2% of whole-farm losses at a rate of only 0.1 kg P/ha/yr from the FDE block. The combination of deferred irrigation with low application rate tools predicts a zero direct loss of P from FDE on a soil that has a high inherent risk of preferential flow and direct losses. Losses from daily FDE application using a travelling irrigator at slow and fast speed on a well drained soil was predicted to make up c. 25% and 15% respectively of whole-farm P losses (Figure 9). However, as whole-farm P losses are very small in magnitude on well drained soils (0.1 kg P/ha/yr compared with with 0.9 kg P/ha/yr from the poorly drained Pukemutu silt loam), these losses corresponded to direct FDE P losses of only 0.2 and 0.1 kg P/ha/yr from the FDE block respectively. The inclusion of either deferred irrigation or low-rate tools was predicted to eliminate all direct P loss from FDE.

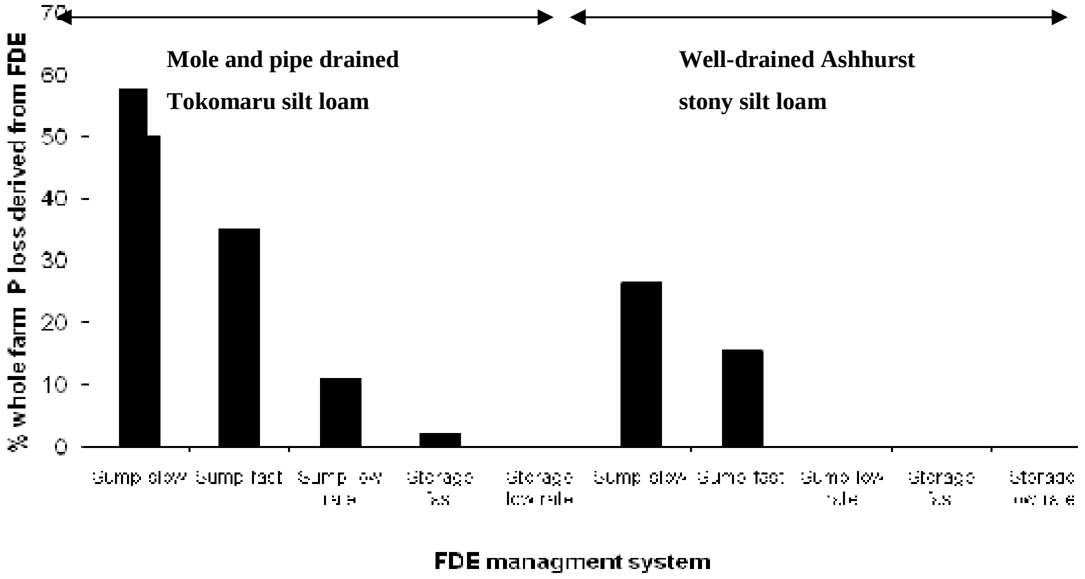

Figure 9. The influence of different effluent management practices on P loss as a percentage of whole-farm P loss.

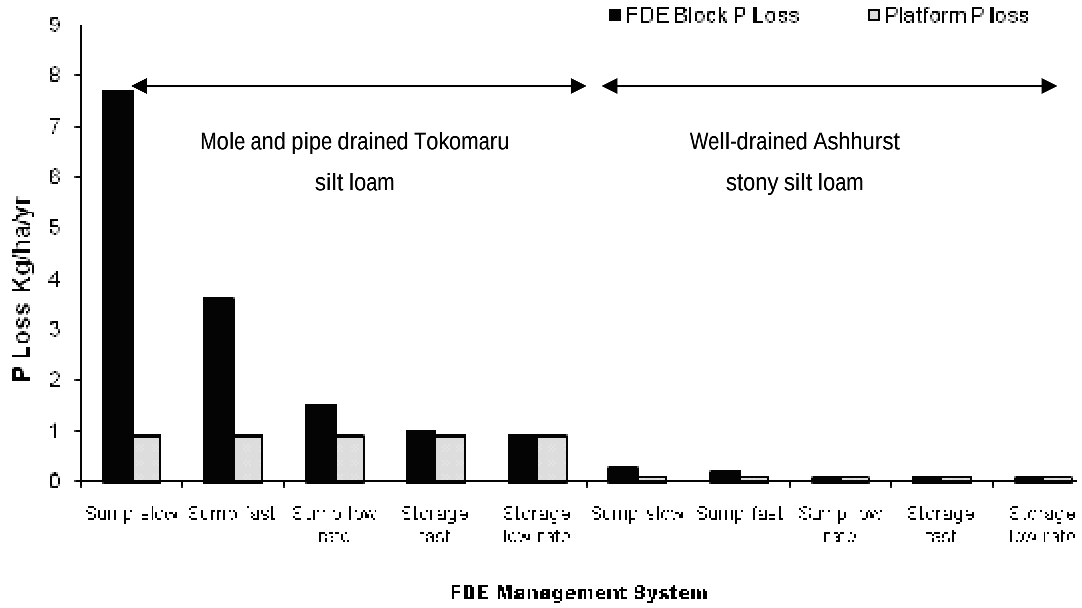

Figure 10. The influence of different effluent management practices on per hectare P loss from the effluent block and platform (non-effluent) area.

What are the environmental effects of ponding?

47. Ponding can be generated by two different processes. The first process is termed ‘infiltration excess’. Such conditions imply that rainfall (or irrigation) intensity exceeds the soil’s surface infiltration rate. On flat land this condition will result in surface ponding. A suitable lag time is required post-rainfall and/or POST-FDE irrigation for all of the ponded surface water to infiltrate the soil body. However, on sloping land ponded water will move downslope, hence creating surface run-off or overland flow. Natural soil properties can influence soil infiltration rate, as can soil physical damage induced by grazing animals. Soils with massive or platy soil structure are prone to infiltration-excess conditions. The second process that results in ponding is known as ‘saturation excess’. This condition requires a fully saturated soil, often as a result of a high water table or a slowly permeable subsoil layer that restricts drainage. Saturated soils are filled beyond field capacity to the point that all large and typically air-filled pores are filled with water. Once all pores are storing water, the soil has no capacity to infiltrate further water and it therefore ponds or flows downslope. Overland flow will stop once the water source is removed. However, saturated soil profiles can only be alleviated by drainage or evapotranspiration.

48. Ponding itself is not the contamination point for direct loss of FDE but an indicator that preferential flow conditions are to be expected. Where infiltration-excess ponding occurs

on flat land with no direct pathway to a nearby water source, the environmental impact will be low. Such ponding will reflect a discrepancy between FDE application rate and soil infiltration rate. So long as an appropriate depth of FDE has been applied (ie. < 20 mm) then all ponded FDE should be absorbed within one to two hours of application. The creation of saturation-excess conditions following FDE application is an indicator of more serious ponding and suggests that direct losses of applied FDE will eventuate. The provision of suitable pond storage and adherence to a deferred irrigation strategy will eliminate the occurrence of saturation-excess ponding. Well drained soils will not typically achieve a state of saturation as they lack the drainage impediment usually required.

Revised decision tool for recommendations on minimum appropriate management of Farm Dairy Effluent (FDE) taking into account soil and landscape features

49. The BMP flow charts presented in section 31 have been modified and presented as Table 1 and Table 2 in order to better represent the minimum appropriate management of FDE while still taking into account soil and landscape features. Storage requirements presented in Table 2 are a guide. Actual storage requirements should be calculated on a site-specific basis, as described in section 50 below. This decision tool varies in three places from the original charts:

    i. The inclusion of a clause for coarse soil structure has been added to the artificial drainage category, to reflect the high degree of preferential flow of applied FDE in soils with coarse soil structures, as reported by McLeod *et al*. (2008).
    ii. The recommended threshold for sloping land has been increased from 5° to 8°. This was changed in order to be consistent with the New Zealand Land Use Capability Survey Handbook.
    iii. The earlier best practice storage requirements listed for well drained land have been changed to reflect minimum appropriate management, considering the low potential environmental risk of this category. The caveat for the low or close to zero storage recommendation is that travelling irrigators should be run at their fastest speed when soil is close to, at, or beyond field capacity.

Table 1. Suggested minimum criteria for a land-applied effluent management system to achieve.

Soil and landscape feature	Artificial drainage or coarse soil structure	Impeded drainage or low infiltration rate	Sloping land (>8°)	Well drained flat land (<8°)
Application depth (mm)	< SWD*	< SWD	< SWD	< 50% of WHC$^{\#}$
Application rate (mm/hr)	N/A	N/A	< soil infiltration rate	N/A
Storage requirement	Apply only when SWD exists	Apply only when SWD exists	Apply only when SWD exists	Avoid application during rainfall
Maximum N load	150 kg N/ha/yr	150 kg N/ha/yr	150 kg N/ha/yr	150 kg N/ha/yr

* SWD = soil water deficit $^{\#}$WHC = water holding capacity

Table 2. Revised decision tool for matching FDE management practice with soil and landscape features. The storage guideline is based on soils with an annual rainfall <1,100 mm.

Soil and landscape feature	Artificial drainage or coarse soil structure		Impeded drainage or low infiltration rate		Sloping land (>8°)			Well drained flat land (<8°)	
Infiltration rate	N/A		N/A		<100 mm/hr	> 100 mm/hr		N/A	
Irrigator hardware	LR^{XX}	TI$^{\#}$	LR	TI	LR	LR	TI	LR	TI
Minimum SWD* (mm)	8	15	8	15	8	8	15	0	0
Storage guide (weeks)	8	12	8	12	8	8	12	1 day	3 days

$^{\#}$ TI = Travelling irrigator, ^{XX}LR = low rate irrigator, * SWD = soil water deficit

Determining pond storage requirements – the pond size calculator

50. Storage requirements to meet deferred irrigation criteria vary with climate and the risk associated with land applying FDE to the soil type present. A simulation of storage requirements for the Massey University No. 4 dairy farm (1,000 mm annual rainfall) was based on actual farm parameters (soil type, effluent block and herd size). It was conducted using 30-year historical meteorological data, and a required water deficit of 15 mm before application could begin. A rotating twin boom traveling irrigator was used. This modeling showed that an appropriate storage requirement for a dairy farm with annual rainfall of 1,000 mm, using a traveling irrigator, would be approximately 4 m^3/cow, assuming a wash-down use of 50L/cow/day. This would equate to 11 weeks of spring storage. If properties were to adopt deferred irrigation in tandem with low-rate application tools, then the greater degree of flexibility of application depths and potential

for increased attenuation would therefore allow the safe application of low depths at times of low soil water deficit. Therefore, storage requirements may be as low as half of those for a traveling irrigator, which requires a greater soil water deficit before FDE application can safely begin.

51. The Massey University No. 4 dairy farm rainfall scenario covers approximately two-thirds of dairy farms in Horizons' Region. However, considering the large variation in rainfall distribution and the site-specific nature of yard wash-down requirements (yard size, water pressure, uptake of water minimisation methods and equipment), each dairy property ideally needs to calculate its own storage requirements. To enable more site-specific calculations, Massey University has developed a pond storage calculator for use in Horizons' Region (Horne *et al*., 2009). In summary, this applied and farmer-friendly tool calculates a recommended pond storage requirement from the following model inputs:

- Soil available water holding capacity (mm)
- Number of cows milked
- Yard area (m^2)
- Shed area (m^2)
- Feed-pad area (m^2)
- Milking hours/day
- Pond area/cow
- Trigger soil moisture deficit before application of FDE can commence
- Irrigation volume applied at trigger deficit
- Irrigation depth at trigger deficit
- Wash-down water/cow/day
- Area irrigated with FDE
- Start milking date
- Stop milking date
- Rainfall data from chosen metmeteorological stations
- Start irrigation date

Why do farm dairy effluent ponds need to be sealed?

52. If deferred irrigation is going to be implemented for land application of FDE, then the existence of suitable pond storage will be an essential element. Many properties do not have any existing storage capacity, while some properties with existing ponds originated from old two-pond treatment systems that are now used for storage prior to application to land.

53. Ponds pose a potential risk to shallow groundwater contamination if they are not adequately sealed. In particular, some existing ponds are sited next to waterways for ease of discharge during two pond treatment. Unsealed or inadequately sealed ponds are essentially a continuous point source discharge of effluent contaminants, and this reduces the potential for re-use of nutrients by plant uptake.

What are the effects of not sealing ponds, ie. potential contaminant loss from an unsealed pond?

54. A desktop assessment of the potential contaminant loss (N and P) under a range of different pond leakage rates is presented in Table 3. The assessment assumes that effluent is only in the pond and available for pond leakage during the lactation season (270 days). The concentrations of N and P in the pond-stored FDE are assumed to be 200 mg N/L and 30 mg P/L respectively. The simulated pond is 1,000 m^2. A near fully-sealed pond with a leakage rate of 1x10^{-9} m/s is calculated to lose 4.67 kg N and 0.7 kg P per year. If the pond was somewhat leaky, with a leakage rate of 1x10^{-7} m/s (equivalent of c. 9 mm/day), then the annual loss would be 467 kg N and 70 kg P. Assuming that this pond received effluent from 500 cows, and that each cow produced 13.5 m^3 of FDE per year based on 50 L/cow/day, then this would represent a loss of approximately one third of the daily volume of wash-down inputs. Furthermore, assuming that each cow excretes on average 6.5 kg N and 1 kg of P per year into the dairy yard, it is, therefore, estimated that approximately 14% of N and P FDE inputs would be lost through pond leakage. A further scenario is provided for a pond leakage rate of 1x10^{-6} m/s (equivalent of c. 90 mm/day). However, it is noted that at this leakage rate the pond empties faster than FDE is generated at the milking shed.

Table 3. Estimated daily and yearly pond loss of N and P under a range of different pond leakage rates. Figures are determined for a 500 cow herd.

Drainage rate		Drainage volume	N loss		P Loss	
m/s	mm/day	(L/day)	(kg/day)	(kg/yr)	(kg/day)	(kg/yr)
1.00E-	0.0864	86.4	0.01728	4.67	0.0026	0.70
1.00E-	0.864	864	0.1728	46.7	0.026	7.0
3.80E-	3.28	3283	0.66	177.3	0.10	26.6
1.00E-	8.64	8640	1.728	467	0.26	70
1.00E-	86.4	86400	17.28	4666	2.6	700

What is an appropriate sealing requirement?

55. Proposed One Plan Rule 13.6 currently states that all FDE ponds must be sealed to a permeability of less than 1x 10^{-9} m/s. Given the assessment above, this relates to a leakage of less than 0.1 mm/day or approximately 23 mm over the duration of the milking season. However, a requirement for a near-zero leakage of FDE through a pond would likely exclude pond construction with a clay base liner and therefore such a limit would not be practically achieved. Environment Southland (2009) have suggested a higher leakage of 3.8 x 10^{-8} m/s in order to more practically allow clay-lined ponds

How can permeability of ponds be tested on new and existing ponds?

56. Permeability testing of ponds will require appropriate assessment and certification by a qualified engineer of the pond liner or clay base. An alternative approach may be to carry out a mass balance assessment of the volume of FDE inputs (inflowing FDE and direct rainfall) and outputs (pumped FDE, evaporation) to determine the leakage component.

How can ponds be sealed?

57. Ponds can be sealed using clay liners or a range of artificial liners such as polyethylene, polypropylene and concrete. A recently released code of practice for design and construction of agricultural effluent ponds by Environment Southland (Environment Southland 2009) recommends that the installation of a farm dairy effluent pond requires the supervision of a suitably qualified engineer (civil or agricultural) with experience in soil and earthworks. Furthermore, I suggest that all ponds should be built in accordance with the standards presented in Dairy NZ's Managing Farm Dairy Effluent manual (2006); section 3.6.

58. The installation of a clay base will require an assessment of soil properties such as texture and its propensity for slaking, dispersion and shrinkage. Furthermore, the construction process will require that clays are at the appropriate soil moisture content to enhance soil compaction. Both clay and artificially lined ponds will need to be managed in such a way that maintenance activities do not damage the integrity of the pond seal. A summary design and construction criteria for clay and artificial lined ponds is provided by Environment Southland (2009).

How much does it cost to construct and seal a pond?

59. Data derived from the AgResearch BMP Toolbox (refer also to evidence to be presented to the Hearing by Dr Ross Monaghan) calculates the cost of building a plastic-lined pond with 2,000 cubic metres of storage at $25,000. This equates to enough storage for 80 days (11 weeks) for a herd of 500 cows (assuming all rainfall is diverted from the wash-down yard and shed roof, and wash-down is generated at a rate of 50L/cow/day), at a setup cost of c. $50/cow. This would also be enough storage for 16 weeks for a herd of 350 cows, at a cost of $71/cow. Dr Monaghan’s technical evidence suggests that the typical capital cost range for building effluent storage ponds will vary between $35/cow and $100+/cow, depending upon pond size and lining requirements. The cost for heavy duty polyethylene plastic liner (1 mm thick) is c. $12/m^2.

60. The additional cost of converting to low-rate irrigation depends upon the existing infrastructure. Assuming that appropriate pond storage was already in place, the upgrade cost from a traditional travelling irrigator to a set of 24 K-line pods with a sludge bed to capture solids would be $17/cow for a 350-cow herd, or $12.60/cow for a 500-cow herd. If the sludge bed was replaced with a solids separator, then the cost (including the pods and piping) would be $85 or $60/cow for 350-cow and 500-cow herds, respectively. The cost of upgrading to a Larall-type system is less easy to price as the system requires a lot of piping and hydrant infrastructure. Therefore, the applicability of existing infrastructure has a considerable impact on the end cost. The designers of the Larall system say that most setups that include pipe infrastructure and a lined pond cost between $1,500 and $2,500 per ha. This equates to a total setup cost of between $96/cow to $146/cow for a 500-cow herd.

Dealing with solids and solid separation

61. If FDE is stored in ponds, then effluent solids become part of the effluent management programme. Without stirring, sediment will sink to the bottom of a pond and form a nutrient rich sludge that will need to be periodically cleaned out. The frequency of such an operation depends on both the pond and herd size, and typically occurs every 2-5 years. Some farms keep their FDE ponds well stirred (via mechanical means) to prevent the build up of sediment sludge, and therefore regularly irrigate it combined in solution with the liquid FDE. Such an operation can be achieved with most travelling irrigators. However, most low-rate irrigation tools, with their small nozzle size, require some degree of solid separation to avoid blockages. Screw press solid separators are commercially available in New Zealand but come at a high cost (section 59). A cheaper

alternative, known as a 'sludge bed' or 'weeping wall' system has recently been widely adopted in Southland. The sludge bed separates sediment from the liquid effluent in order to provide FDE suitable for application using small nozzle irrigation systems. Sludge beds contain a solid reservoir in front of a slatted wooden wall that gravity feeds liquid effluent to a storage pond. The liquid effluent is suitable for application through any irrigation system.

62. New Zealand literature on the separation ratios between separated solid and liquid (soluble) effluent contents is light. However, a summary of analytical assessments of some different New Zealand effluent products by Longhurst *et al*. (2000) demonstrates the nutrient-rich nature of sludges and slurries from separated effluent solids. These concentrated products will have different management implications than that of liquid FDE and are the subject of some new research about to be undertaken by AgResearch Ltd. In the meantime, it is important for farmers to understand the nutrient concentration of these separated solids so that land applications can be managed, taking into account consent conditions (N loading limits) and agronomic factors such as nutrient inputs, nutrient release rates and pasture survival at time of application.

What is the annual value of the nutrient that could be returned to a farming system from farm dairy effluent (FDE)?

63. FDE is an important source of collected nutrients. If these nutrients are returned to land in a manner that keeps them in the root zone, then their nutrient value can be utilised for plant uptake. Calculations of the annual value of nutrients in FDE are based on the following values for N, P, K, and S derived from the Ravensdown fertiliser price list in April 2009 (http://www.ravensdown.co.nz).

i. N - $1.51/kg
ii. P - $4.35/kg
iii. K - $2.05/kg
iv. S - $0.95/kg

64. Two case studies are presented to highlight the annual nutrient value collected in FDE. The case studies were assessed using the OVERSEER model:

i. Scenario One is based on a hypothetical farm with a milking platform of 225 ha and stocking rate of 3.2 cows/ha producing 1,056 kg milk solids/ha/yr on a fully grass-based system. Cows are wintered off during the winter and fertiliser additions are made to maintain an Olsen P of 30.

ii. Scenario Two is the same as Scenario One except it is a high supplement farm which imports 720 tonne of extra dry matter fed on a feed-pad to support a further 180 cows, at a stocking rate of 4 cows/ha, and produces a total of 1,330 kg milk solids/ha/yr.

iii. The annual value of nutrient returned to land in FDE from the pasture-only system was approximately $24,000 ($33.50/cow), which represented 21% of the annual fertiliser cost (Table 4). The annual value of nutrient returned to land in FDE from the high supplement farm was approximately $115,000 ($160/cow) which represented 75% of the annual fertiliser cost.

Table 4. Case study comparison of nutrient quantities and value from a pasture-only system (Scenario One) vs. a high-feed supplement farm (Scenario Two).

	Scenario One			Scenario Two		
	Total kg/yr	$/yr	$/cow/yr	Total kg/yr	$/yr	$/cow/yr
N	5889	8,892	12.35	29679	44,815	62.24
P	663	2,884	4.01	2808	12,214	16.96
K	5850	11,992	16.65	27300	55,965	77.73
S	312	296	0.41	2067	1,963	2.73
Total		24,064	33.42		114,957	159.66

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