CHOOSING THE RIGHT EFFLUENT SYSTEM

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Introduction

For some time now, dairy farmers have been under pressure to install effluent systems to ensure contamination of surface and groundwater from poorly designed or performing effluent irrigation systems is eliminated. To achieve this, systems need to fit the purpose and demands of each individual farm.

In the past, some farmers have invested significant amounts of money in installing a new or upgraded effluent system to find that it still has fundamental flaws and will never perform to the standard required. To help prevent this from happening, a Code of Practice (COP) has been developed by the effluent industry setting minimum standards. Alongside this, an accreditation scheme allows those system designers who have met the rigorous accreditation application criteria to display the accreditation tick. For more information about effluent accreditation, go to www.effluentaccreditation.co.nz.

It is crucial that farmers understand the concepts of what a fit for purpose "good" effluent system entails. Of key importance is understanding that soil type on the farm dictates many of the decisions made. Soil type has a huge implication on the number of days per year that effluent irrigation can take place, and the depth effluent can be applied which impacts hugely on the volume of effluent storage required.

Gone are the days when a farmer made effluent system design decisions based solely on the volume of effluent produced from the dairy shed, e.g. number of cows x average litres water per cow x how many days storage they thought their local council required. This has been turned completely upside down to first look at the farm's soil types to determine effluent application criteria, then effluent generation inputs (e.g. cow numbers, dairy shed water use, catchment areas etc.), followed by 30 years of climate data to finally determine system design and subsequent appropriate storage volumes going forward. The tool most regional councils are using to determine required effluent storage requirements is the Dairy Effluent Storage Calculator (DESC). This calculates the required storage on individual farms by running a daily soil water balance and deciding on a daily basis whether effluent can be irrigated or should be directed to storage.

Soil types on the farm and effluent block

Soil type (or more accurately soil risk of effluent run-off or preferential flow to drainage) is by far the largest influencer on effluent storage volume for dairy farms in New Zealand. All soils throughout New Zealand have now been classified for effluent irrigation risk fitting into one of five categories, as seen in Table 1.

Table 1: Soil risk framework.

Category	A	B	C	D	E
Soil and landscape feature	Artificial drainage or coarse soil structure	Impeded drainage or low infiltration rate	Sloping land (>7°) or land with hump & hollow drainage	Well drained flat land (<7°)	Other well drained but very light flat land (<7°)
Risk	High	High	High	Low	Low
Application depth (mm)	< SWD[1]	< SWD	< SWD	< 50% of PAW[2]	≤ 10 mm & < 50% of PAW[2]
Storage requirement	Apply only when SWD exists	Apply only when SWD exists	Apply only when SWD exists	24 hours drainage post saturation	24 hours drainage post saturation
Max depth: High rate tool	10 mm	10 mm	10 mm[3]	25 mm[4] (10 mm at field capacity)	10 mm
Max depth: Low rate tool	25 mm	25 mm	10 mm	25 mm	10 mm

[1] SWD is the soil water deficit

[2] PAW is the plant available water in the top 300 mm of soil

[3] Only applicable when instantaneous application rate from the irrigator is less than the infiltration rate

[4] Suggested maximum application depth when a suitable SWD exists (≥ 15 mm)

For all the risk categories the application rate should always be less than the soil infiltration rate otherwise you will get ponding (on sloping land the instantaneous application rate needs to be less than the soil infiltration rate or you will get run-off).

Whilst farmers do not have control of the soil risk on their farm, in situations where they have a combination of High and Low Risk soils they do have control over which soils get irrigated with farm dairy effluent (FDE). With soil risk having such a large influence on storage volumes, and therefore solids management, it is often more cost effective to pump FDE greater distances to Low Risk soils than to build the infrastructure needed for large storage volumes and solids management.

Figure 1 below suggests decisions to be addressed when designing an effluent system depending on soil risk of the effluent block.

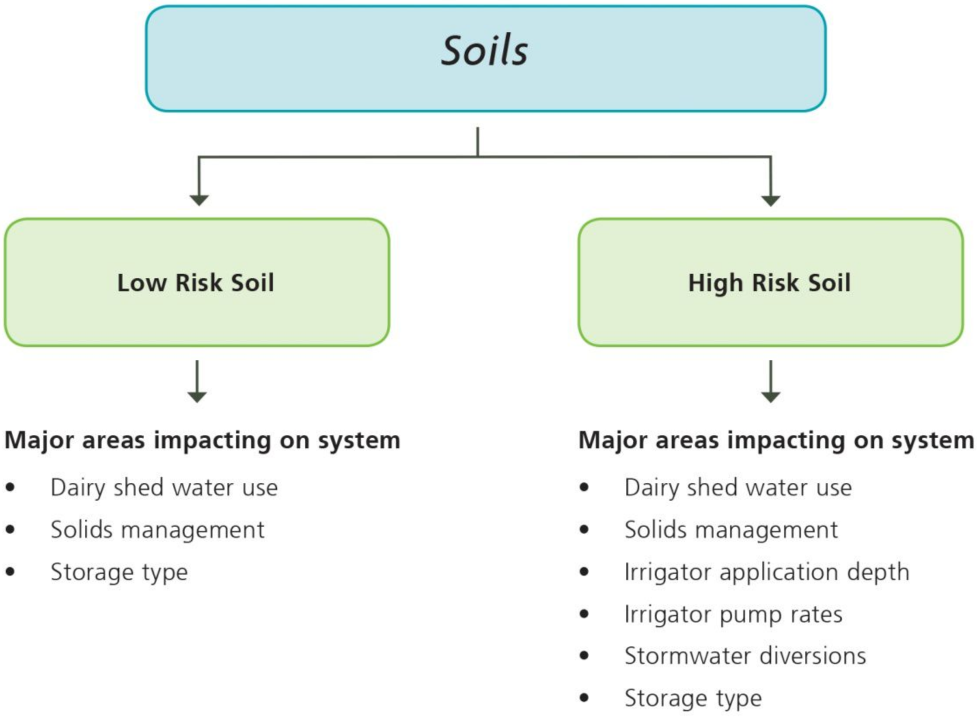

Figure 1. System choices based on soil risk

High Risk Soils

These soils have a high risk of run-off or preferential flow paths and therefore need application of effluent at depths not exceeding soil moisture deficit. For this reason, effluent application methods become critical during the wetter cooler months of the year when evapotranspiration rates are low and, subsequently, soil moisture deficits are small and often infrequent. If we are to take advantage of these small soil water deficits, low depth application needs to be installed.

Low Risk Soils

These soils have matrix flow characteristics whereby the applied effluent is in contact with a much greater portion of soil particles as it percolates down through the soil profile; this enables nutrients to be stripped from the effluent and be held within the soil matrix. Due to this quite different flow path through the soil profile, these soils do not require deficit irrigation to take place. Therefore, if a low risk soil has received rainfall and induced a drainage event (the soil has gone beyond field capacity), then effluent can be applied the day after this event has ceased. There is no need to wait for a soil moisture deficit greater than applied effluent.

The impact of soil risk on required storage

An example Winton dairy farm, milking 500 cows, demonstrates the difference in the number of annual effluent irrigation days between high and low risk soils. This example farm uses industry average water use, catchment areas and pump rates, and applies effluent at a depth of 10 mm. With the entire effluent block on High Risk soils, the farm needs approximately 5700 m^3 of storage (a pond 50 m x 50 m x 4 m deep) to meet the FDE Code of Practice. In comparison, this same farm which is now on Low Risk soils needs only 720 m^3 of storage (25 m x 20 m x 4 m deep). This is a reduction of storage requirements of approximately 85%. To demonstrate this further, if the farm has only 50% of the effluent block on Low Risk soil, the storage requirements are approximately 1300 m^3, a reduction of about 75% from the High Risk soil example.

The take home message is to identify all areas with Low Risk soils on your farms. Even if you only have a small portion available, and even if it requires a greater pumping distance than your current system, the advantages in storage reduction are significant.

Water use in the farm Dairy

Water use in the dairy shed and yard has a large impact on storage requirements. In general, for a normal herringbone shed using 70l water/cow/day, 10% of the water is used for plant washing, 25% is used for hosing out the bail area and the rest (65%) is used to hose the yard. Therefore, by installing a green water recycling yard washing system, daily water use in and around the farm dairy can be slashed by approximately 65%. For the Winton dairy shed milking 500 cows, this saves nearly 23,000 litres of water per day. This equates to 23,000 litres not pumped from the ground or surface water body and 23,000 litres not pumped out through an effluent irrigation system; at an effluent pump rate of 5 litres per second, this is a saving of 75 minutes of effluent irrigation every day of the season!

The above example shows the easy gains of reduced freshwater abstraction, electricity use and labour by installing a green water yard washing system. Similarly, there are often significant financial gains around effluent storage volume requirements by installing a green water yard wash. Using our Winton example with all High Risk soil, approximately 5700 m^3 of storage would be required (50 m x 50 m x 4 m deep) at 70 l water use/cow (35,000 l/day). With a green water yard wash installed, water use has dropped to 12,600 litres/day (25 l/cow) and storage volume requirements has decreased to approximately 2400 m^3 (40 m x 30 m x 4 m deep). This equates to a reduction in required storage of approximately 3300 m^3 or 42%. Installing a green water wash system that replaces a hand held hosing system would provide some significant labour savings on a daily basis as well.

A green water yard washing systems needs to be designed to ensure any green water used is from "settled" storage, and therefore has had solids removed to prevent a build-up of sediment on the dairy yard and to minimise odours. It is also necessary to be able to wash the dairy yard with clean water if needed. It makes good sense to be saving a valuable resource, saving time, effort and money on pumping effluent and managing irrigators, and well as reducing storage costs.

Solids Management.

This is where the options become more variable and farmer preferences can be used. In this context, solids are the organic matter portion of FDE after sand and stones have been removed by a well-designed sand trap. This includes undigested fibre, sediment, grass, hair etc.

Whilst not always necessary to separate solids, they do need to be considered and managed. There are a number of factors that need to be addressed when deciding on solids management systems. These include:

- Herd size
- Soil Risk
- System configuration i.e. if all effluent goes to storage prior to any irrigation
- Solids generation e.g. feed pad, barn etc.
- Green water recycling

In general, if the farm has low solids generation (no feed pad), an effluent block consisting of a minimum of 50% Low Risk soils, and daily effluent irrigation takes place from a sump (thereby irrigating all of the solids generated on a daily basis within the liquid FDE), then the need to separate soils is minimal. In these situations, solids captured in the storage pond or tank can be managed via agitation of the storage facility and/or an annual de-sludge process. However, if the system differs from that above then solids separation becomes more important. These situations include:

- Farms that direct all effluent to storage facilities and then pump off the pond
- Farms on High Risk soils. This is due to prolonged periods of effluent being discharged into the ponds before irrigation can take place
- Farms generating lots of solids e.g. a feed pad
- Farms with green water recycling

There are a number of methods of solids separation and no one system is best. Your choice of solids separation will depend on capital available, ability to utilise gravity, ability to utilise current infrastructure (e.g. sumps), desired level of separation, desired level of moisture content of separated solids and, in some cases, sufficient electricity supply. It may also be prudent to consider catchment area of your solids separation system, particularly in high rainfall areas.

Methods of solid separation include:

- Two pond system (settling pond and storage pond)
- Weeping walls
- Screw press
- Slope screen
- Rotating drum

Both the two pond and weeping wall systems work best if there is enough fall within the farm system to utilise gravity for transporting the liquid effluent. They both require a method of removing solids from within them without compromising the pond/bunker lining and usually have a larger footprint than mechanical separation systems. This may impact significantly on storage requirements in higher rainfall areas due to the increased footprint capturing larger volumes of rainfall.

The three mechanical separation processes (screw press, slope screen and rotating drum) all work best when effluent is collected in a large agitated sump to provide the separator with effluent of a regular consistency. All three systems require effluent to be pumped into the separators at specific rates depending on the separation type. In general, screw presses will remove the most liquid, providing solids with the least moisture content, but will use more electricity and tend to have higher maintenance costs due to forces required to “squeeze” the liquid from the solids. Conversely, slope screens and rotary drums tend to have a “wetter” solids output but have less wear and energy costs.

It is important to place the separator near the front of the bunker to enable separated solids to be pushed to the rear of the bunker for storage. Too often solids separators are mounted on the back walls of bunkers, thereby making the front of the bunkers redundant for solids storage; it is much easier to push the solids to the back rather than try pulling them to the front.

When installing any of the above systems, it is important to correctly calculate the volume of separated solids that will be collected to determine a bunker size. IPENZ Practice Note 27 –Dairy Farm Infrastructure has guidance on calculating this.

Effluent Application Depth

On high risk soils, effluent irrigation can only take place when the soil water deficit is greater than the applied depth of effluent. Therefore, if irrigation methods that apply shallow depths of effluent is utilised, a greater number of irrigation days will be available each year. To illustrate this, the twelve month period of soil water deficit at the Winton site in 2002 is shown below in figure 2.

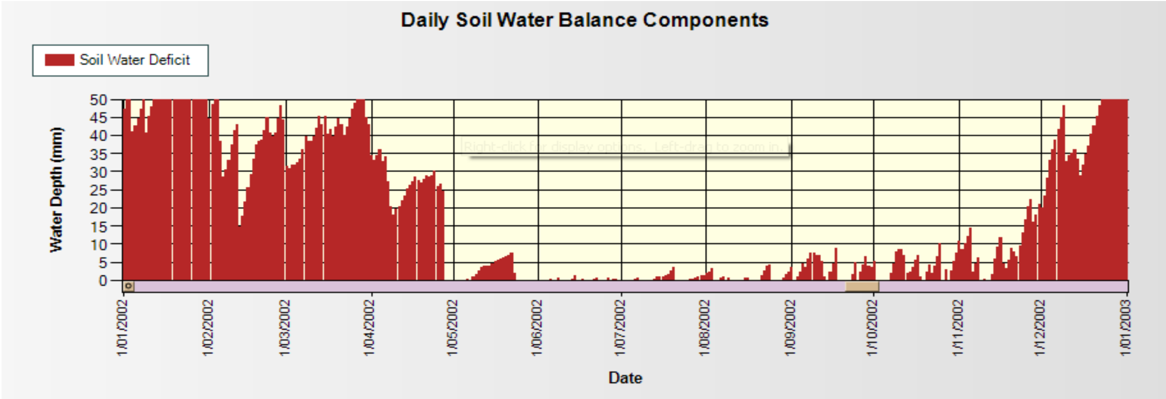

Figure 2. Daily soil water deficit at Winton 1 January 2002 to 31 December 2002

From the period 28th April to 24th November (211 days) in 2002, there were 65 irrigation days at 3 mm application depth, 40 irrigation days at 5 mm application depth and only 7 irrigation days at 10 mm application depth. This is shown in table 2.

Table 2. Irrigation days available for 3mm, 5mm and 10mm application depths

Month	Days	Days irrigation available		
		3 mm application	5 mm application	10 mm application
April	3			
May	31	12	7	
June	30			
July	31	1		
Aug	31	4		
Sep	30	16	9	
Oct	31	17	12	3
Nov	24	15	12	4
Total	**211**	**65**	**40**	**7**

If an average system is pumping 5.5 l/s (20 m^3/hour) on the days that effluent irrigation can take place over this period it would have pumped from the storage facility 5200 m^3 of effluent at 3 mm depth, 3200 m^3 at 5 mm application depth and only 560 m^3 at 10 mm

This translates into a significant reduction in storage volumes. Continuing with the average Winton dairy farm example, the 10 mm aplication depth calculation requires approximately 5700 m^3 of storage, the 5 mm application depth calculation requires approximately 4000 m^3 of storage and the 3 mm application depth calculation requires only 2660 m^3 storage shown in table 3.

Table 3. Storage volumes required under 3 mm,5 mm and 10 mm application depths.

Application	Potential dimensions	Storage requirement	Storage reduction

Depth	(m)	(m^3)	
10 mm	50 x 50 x 4	5700	
5 mm	43 x 42 x 4	3950	30%
3 mm	38 x 35 x 4	2660	53%

Effluent Pump rates

Effluent pump rates do have an influence on storage requirements but to a lesser degree, particularly with higher application depths. This is because there are minimal days of pumping available at the higher application depths to take advantage of the increased infrastructure required to pump at greater rates. Table 4 shows the impact of doubling winter-spring effluent pump rates over the various application depths. It can be seen there is little to be gained by doubling pump rates for the 10 mm application depth system, yet there is quite a saving in storage requirements at the 3 mm application depth example.

Table 4. Impact of pump rates on storage requirements

Application Depth	Storage requirement(m^3) for 80 m^3/day pump rate	Storage requirement(m^3) for 160 m^3/day pump rate	Storage reduction
10mm	5700	5400	5%
5mm	3950	3200	19%
3mm	2660	1850	30%

Storm water Diversions

In reality, most storm water diversions have less impact than initially thought. The exception to this is in high rainfall areas where storm water can significantly increase storage requirements. Regardless of annual rainfall, it is common sense to have a storm water diversion in place for the winter period when the cows are dry and nowhere near the dairy yard. There is an option to select within the DESC for storm water diversions, either on a daily basis (all season) or only when the cows are dry.

All the worked examples discussed so far in this paper have been with a winter diversion in place for a spring calving farm. If there had been no storm water diversion in place, there would have been a requirement for an additional ~200 m^3 of storage, regardless of application depth of irrigated effluent. Conversely, if there had been daily storm water diversion in place, there would have been a reduction of required storage of between 150m^3 and 300m^3.

Storage options

There are a number of factors to bear in mind when considering storage options.

Pond dimensions.

It needs to be remembered that storage facilities (ponds or tanks) are also catchment areas for rainfall. Therefore, deep ponds with smaller surface areas have less storage requirements than shallow ponds, particularly in high rainfall areas. It is also worth having the discussion with your pond lining company for the best pond dimensions that fit their liner widths.

Pond depths not only have an impact on storage requirements but also on cost. In general, it is cheaper to build a deeper pond with smaller surface area dimensions than a large area shallow pond. However, there is a limit to depths, particularly for drawing effluent out and maintenance of sludge etc. Depth also appears to have an impact on pond odours, with deep ponds likely to turn anaerobic more quickly than shallow ponds.

Pond wall batters also have an influence on storage requirements. In general, clay lined ponds should not have batters steeper than 3:1 (3 horizontal to 1 vertical). This is to allow compacting equipment to drive up and down the batters; batters steeper than this make compaction more difficult. Synthetically lined ponds can have batters steeper than this and are regularly at 2:1 with some steeper than this. The outcome of steeper batters is more storage is available per square metre of pond surface area which can make quite a difference in high rainfall areas.

Ground water limitations

Any storage facility (pond, tank, or weeping wall) should not be built below the seasonal high water table due to the risk of them being “floated” out of the ground. Therefore, in areas with high water tables, ponds and tanks need to be above ground. This can have a huge impact on the cost of building these, particularly if thousands of cubic metres of fill needs to be trucked in to build pond walls.

Ponds vs Tanks

This can often come down to farmer preference. Tanks may seem like a more expensive option, but are not always so. Tanks can often be cost comparable in situations where very small storage volumes are required, and for flat farms with high water tables and no fill to build an above ground pond. In areas of high rainfall tanks can be covered much easier than ponds to prevent rainfall from entering the tank. Tanks also go up fast and are immediately fenced off for stock and children access.

Summary

Of all the variables on farm, by far the one with the most influence on FDE system design and storage requirements is soil risk of the effluent block.

Low Risk soils enable us to irrigate FDE much more frequently than the High Risk soils, enabling farms to have significantly reduced storage requirements and often reduced infrastructure around solids management.

If we are required to irrigate FDE onto High Risk soils over the wetter cooler months, when evapotranspiration rates are low, then low depth irrigation methods should be employed to take advantage of the small soil moisture deficits that can occur over these months. Failure to do this will result in large storage facilities being built on farm at considerable cost.

FDE solids management needs to be addressed regardless of FDE system design. The variation on whether solids are managed via agitation or separated will be dictated by the volume of solids generated in and around the farm dairy and feed pad, soil risk of the effluent block and FDE irrigation technique.

Water use in the dairy is one of the true variables we can choose to have control over. If the farm has FDE storage then there is a readily available source of settled effluent for washing the dairy yard. It just makes good sense to be implementing this technique to reduce on farm energy costs, reduce on farm labour and look after a valuable resource.

One size does not fit all! Just because your neighbour's farm is a similar size and milking a similar number of cows does not mean your effluent systems are similar or storage requirements are the same. We no longer build *x* number of days storage. We now build effluent systems that match the individual farm and the subsequent required storage volume.

No one system is best, and no one system designer has an off the shelf system that suits all farms. With an understanding of how, where and how much on-farm effluent is generated, and where and when effluent is irrigated to which soils on their farms, farmers are now armed with the correct questions of system designers to ensure the system they get is fit for their farm.