Waikato Regional Council Technical Report 2012/03

Assessing environmental compliance of ponding and seepage from dairy feed pads and stand-off areas

www.waikatoregion.govt.nz
ISSN 2230-4355 (Print)
ISSN 2230-4363 (Online)

Prepared by:
Tony Fenton
Alchemists Ltd

For:
Waikato Regional Council
Private Bag 3038
Waikato Mail Centre
HAMILTON 3240

30 September 2011

Document #: 2088068

Peer reviewed by:
David Houlbrooke,
Agresearch January 2012

Approved for release by:
Ross Wightman Date January 2012

Disclaimer

Assessing Environmental Compliance of Ponding and Seepage from Dairy Feed Pads and Stand-off Areas

August 2011

Prepared for Waikato Regional Council by:

Tony Fenton

Alchemists Ltd

Table of Contents

Executive Summary

Wintering systems are increasingly being used in the Waikato to provide improved stock and feed management, protect soils, manage pasture, and to reduce contaminant losses during winter periods. Currently feed pads and standoff pads are the predominant types of wintering systems used. If runoff or seepage from stand-off or feed pad areas is not actively managed it can pose a risk for environmental quality and protection under certain circumstances. Due to this risk Waikato Regional Council need to know what criteria compliance staff could use to assess the significance of likely adverse effects from any non-compliance of these systems.

The purpose of this report is to provide two key outcomes:

1. To evaluate the potential scale of effects of ponding and seepage from feed pads and stand-off pads on the environment.
2. Provide a risk assessment of these activities and provide field guidelines/criteria to assist enforcement officers in determining whether seepage or ponding from a particular dairy stand-off area or feed pad would be a significant non-compliance issue.

Feed and standoff pads can be used to avoid extended grazing on wet soils which can result in extensive pugging that degrades soil structure. This results in pasture damage and increased contaminant runoff. Removing animals from pasture onto a feed/standoff pad between autumn and calving (c. 4 months) can reduce nitrogen (N) loss by 27-60% and reduce phosphorus (P) and E. coli loss.

Recent survey results[1] indicate that for Waikato dairy farmers 21% had feed pads, and most of these farmers collected and managed the effluent generated by these systems (86%). Standoff pads were used by 14 % of dairy farmers, but only half of these (47%) managed the resulting effluent drainage.

Contaminants (N, P, E. coli[2]) loading onto and losses from pads are influenced by the pad type and setup and a range of management practices. A literature review was undertaken to provide values for contaminant loading, loss, and quality of effluent drainage from pad systems.

For standoff pads that use a covering layer of absorbent carbon material (bark, sawdust) the literature would indicate that the quality of effluent drainage is similar in quality to that generated by the farm dairy.

Reported losses of contaminants from other farm activities are provided to put losses generated by pad systems in context. This comparison is not simple as potential losses can vary widely depending on the pad type, its construction and use, animal management and feed types, and weather conditions. Estimates of potential losses from different pad systems are calculated based on a range of assumptions (see Table 8).

[1] Dairy Industry State of Change Report 2010.
[2] E. coli is used as a faecal microbial indicator organism

A well-managed pad can have a minimal ‘contaminant footprint’ compared with farm losses as a result of runoff and leaching from grazed paddocks.

The potential for contamination of surface and groundwater is discussed for the different types of pad systems and the risk factors that influence this are identified. Where there is no adequate collection and management of generated effluent bare hard surfaces for pads increase the potential for surface water contamination as these can generate large volumes of effluent run off. This runoff would eventually either enter a waterway or pond then drain to groundwater. Applying absorbent carbon based material to pads can provide significant treatment of the effluent load (85-95% reduction), but the resulting drainage can still impact on surface and groundwater if not managed correctly. The biggest potential for groundwater contamination is from unsealed pads porous soils and with no absorbent cover. These can result in high level of contaminant loss to groundwater.

The losses of N in drainage effluent and runoff from a poorly constructed and managed stand-off pad can represent a significant portion of the annual losses from a farm. The scale of this impact could even offset the benefits of contaminant loss management that occur across the farm from other management activities. Figure A shows how the potential benefits from stand-off pad use (40% less loss) can be reduced by about a third if the effluent drainage is not managed correctly. Stand-off pads with no effluent management could potentially increase whole farm losses by up to 35%

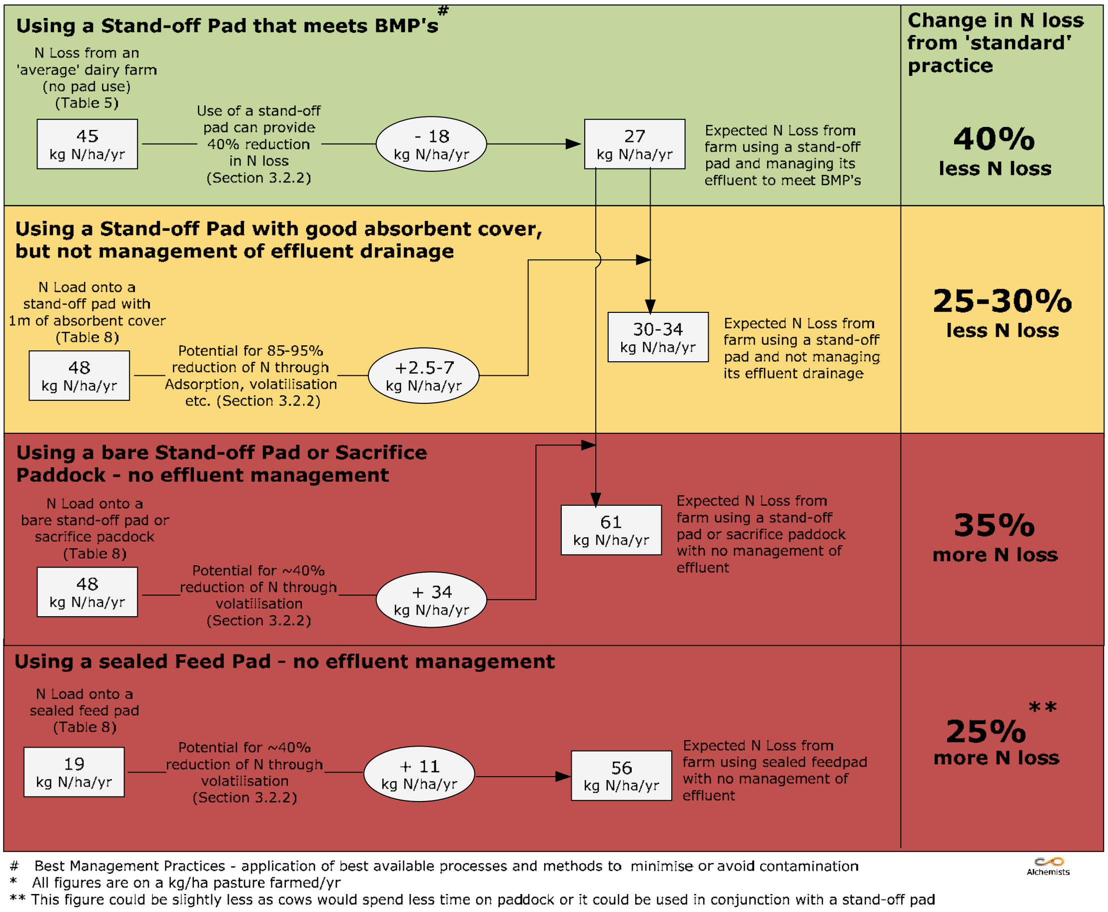

Figure A: Relative effect of different stand–off pad management on farm scale N losses

The potential losses from a feed pad are less (~40% of a stand-off pad loads) as the animals spend less time on these systems. Feed pads could still potentially add significantly to total farm losses if effluent runoff is not managed (up to 25% more N loss from a farm – Figure A).

P losses from sealed pads direct to the waterways could represent a substantial increase in whole farm losses. Potentially P losses in the effluent drainage from a sealed pad with an absorbent cover of bark could result in up to a 40% increase in P loss from a farm if the drainage discharged into a waterway.

Because pads concentrate large volumes of effluent over time into a small area, poor management can create 'point source' management issues and outcomes for receiving waterways.

The key risks from pad systems are identified in order of their relative importance and the factors that need to be considered when assessing the risk of different systems are identified. Assessment of compliance should be consistent with the farm dairy effluent permitted activity rule and prioritising monitoring and compliance effort should use the identified factors to target the most at risk systems.

1 Background

1.1 Purpose of Report

Wintering systems are increasingly being used in the Waikato to provide improved stock and feed management, protect soils, manage pasture, and to reduce contaminant losses during winter periods. Many of these systems include animal shelters or feed and stand-off pads are well managed and follow current best practice. These systems actively manage and treat the effluent that accumulates during their use.

Some Waikato dairy farm feed pads and stand-off areas do not actively manage the effluent generated by their use and this potentially raise issues for contamination of waterways. They often use absorbent material, such as post peelings or saw dust, to contain some of the effluent on pad but these still generate effluent runoff or drainage which can enter waterways causing contamination. Due to this potential for contaminant loss Waikato Regional Council wants to know what criteria consenting staff could use to assess whether or not the intensity of use or any effluent ponding was likely to pose a significant non-compliance issue.

The scope of this report is limited to the potential impact of ponding and seepage from dairy feed and stand-off pads which do not use defined best management practices (BMP's) of sealed pads, capture, storage and effluent spreading.

The purpose of this report is to provide two key outcomes:

1. To evaluate the potential scale of impacts of ponding and seepage from feed pads and stand-off pads on the environment by:
    a. A comprehensive literature review of nutrient, faecal microbes and organic contaminant losses from feed pads or stand-off areas and the risk this poses to water quality.
    b. Assessment of the amount of nutrients and faecal microbial loss that could potentially enter a waterway or drain to groundwater from a feed pad or stand-off area.
    c. Evaluating the significance of this in proportion to losses from the whole farm, the cumulative significance of losses from other farm activities and multiple farms within a catchment.

2. Provide a risk assessment of these activities and provides field guidelines/criteria to assist enforcement officers in determining whether seepage or ponding from a particular dairy stand-off area or feed pad would be a significant non-compliance issue.

To assist the report outcomes context is also provided on the use of pad systems, drivers of regional variability and the assessment and management of risk.

1.2 Feed Pads and Stand-off Pads – Overview of Systems

Detrimental effects of winter grazing

Grazing on wet soils can result in extensive pugging that degrades soil structure by reducing the size, number and continuity of pores (Singleton et al., 2000; Curran-Cournane, 2010). Stock trampling also causes above and below ground damage to pasture plants, reducing vegetation cover and slowing pasture recovery (Singleton et al., 2000; Curran-Cournane, 2010). Compacted soil increases the risk of generating overland flow which can lead to erosion of sediments and transfer of nutrients and faecal microbes from dung and urine to waterways (Luo et al., 2008). Microbial, invertebrate and chemical processes are also affected leaving soil less equipped to filter contaminants (Singleton et al., 2000). Pugging occurs with all stock types, but cattle have the greatest effect on soil physical quality with hoof action extending to a depth of about 20cm in very wet conditions (Curran-Cournane, 2010).

A second major adverse effect of autumn and winter grazing is leaching of contaminants through wet soil with a soil moisture content greater than field capacity. The late autumn-winter period is when peak drainage from pasture occurs and when plant growth and nutrient uptake is the lowest (de Wolde, 2006; Monaghan et al., 2008). Drainage from pasture during this period is one of the key pathways of N loss on farms where cattle are grazed year-round (Monaghan, 2008). Urine patches are the single most important contributor of N (Clark et al., 2010).

Wintering systems

Restricting grazing over the wettest months of the year has become standard practice on many New Zealand dairy and beef farms (DEC, 2006; Monaghan and Longhurst, 2007; Smith et al., 2010; Sonthi, 2010). There are two main reasons that farmers use wintering systems: i) increased production due to better pasture management and animal health and ii) as a best practice mechanism to reduce contaminant loss (de Wolde, 2006; Smith et al., 2010; Sonthi, 2010). Pasture based and forage crop systems are the most commonly used and cheapest ways of restricting winter grazing in New Zealand (Figure 1) (Monaghan and Longhurst, 2007).

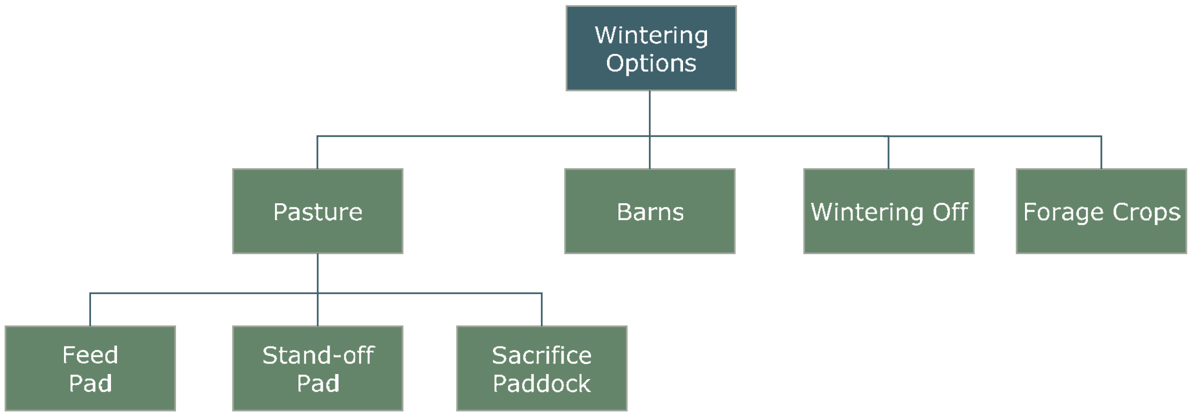

Figure 1 New Zealand wintering systems (from Monaghan and Longhurst, 2007)

Wintering systems can be an effective way of reducing whole farm contaminant loss providing that effluent is contained, stored and applied to land according to best practice (Monaghan et al., 2004; Monaghan and Longhurst, 2007; Smith et al., 2010). Many pasture based systems in New Zealand do not include adequate effluent management systems (Monaghan and Longhurst, 2007) and in the case of sacrifice paddocks or forage crops effective effluent management is not possible unless cattle are restricted to grazing the crop for only a few hours a day (DEXCEL, 2005; McDowell et al., 2005). Conversely, covered systems generally have very good effluent management systems (Monaghan and Longhurst, 2007) but require higher levels of capital input.

The characteristics of wintering systems discussed in the context of this review are as follows:

Animal shelters/tunnel houses (deep litter barns)/wintering barns (scraped concrete floor) – fully covered wintering systems in which the herd spends at least several months. Animal Shelters can have slatted floors and concrete storage bunkers. Wintering barns and tunnel houses generally have a carbon material base (de Wolde, 2006; DEC, 2006; Monaghan and Longhurst, 2007).

Figure 2: Animal Shelter

Feed pads – hard surfaces dedicated to supplementary feeding. Cattle only spend 2-3 hours on the feed pad. Feed pads are used to prevent feed wastage rather than reduce pasture damage (DEXCEL, 2005; Wilcock, 2006; Monaghan and Longhurst, 2007). Feedpads are generally loacated close to the dairy shed for suppliementary feeding of cows after milking. This generally makes incorporation and management of effluent generated easy to incoporate into the farm dairy effluent (FDE) stream.

Figure 3: Feed Pad

Stand-off pads – also termed loafing pads, are purpose built pads that should have a sealed base of compacted clay base or an impermeable lining made of rubber or plastic. These areas are filled with a variable depth of carbon material (woodchip, bark, sawdust – 500-1000mm thick) sand, lime or soft rock. Effluent can be collected and drained from sealed pads whereas effluent from unsealed pads cannot be captured and is lost to the environment in an uncontrolled manner (DEC, 2006; Smith et al., 2010). Stand-off pads do not include provision for supplementary feed as cattle are put out to graze for at least 4 hours a day. Laneways are also used as temporary stand-off areas. These do not include any absorbent material and effluent builds up on the laneway surface.

Figure 4: Standoff (Loafing) Pad

Wintering pads – Similar to stand-off pads but supplementary feed is included as cattle spend two to several months on the pad. A separate hard surface for feed may be allocated or feed may be provided on the pad itself. Uncovered wintering pads will capture all rainfall generating an increase in effluent. Wintering pads may have partial cover (DEC, 2006; Monaghan and Longhurst, 2007). This is the New Zealand equivalent of feedlots/feedpads in the US and Canada.

Sacrifice Paddock – An area of the farm is fenced to hold cows on a normal soil paddock surface for extended periods. As the name suggests these area are 'sacrificed' to protect remaining paddock areas from pugging and compaction during wet periods. Animals are not generally fed on sacrifice paddocks, but are returned to graze pastures for up to four hours per day.

Forage crops – Vegetable crop grown specifically for over-wintering of stock. Cattle can be left on cropped paddocks continuously (unrestricted) or moved between cropped paddocks and pasture or a stand-off pad. Additional feed such as silage is often fed out. Effluent cannot be contained and runoff diverted into drains is likely to flow directly into surface waterways (DEXCEL, 2005; Monaghan, 2008).

1.3 Use of Pad Systems

The primary drivers for the use of feed pad and stand-off pad systems are to avoid wastage of feed, to protect soils from damage which can impact future pasture productivity and to reduce contaminant losses from waterlogged and disturbed soils.

The need for using feed pads is often driven by the type of farm system being used and therefore any requirements for supplementary feeding. The need for stand-off pads or sacrifice paddocks is driven by soil type and topography which vary considerably across the Region. There is limited information on the current use and types of wintering systems in the Waikato Region. However anecdotal information about current use of wintering systems includes:

A recent national survey[3] of 1000 dairy farmers, included 348 from the Waikato region. Results from this relating to wintering system use in the Waikato include:

- In 2010 21% of respondents in the Waikato region had a feed pad, while 2% had a herd home (n = 7) and 4% had a calving pad (n=14).
- Of those with a feed pad, 86% collected run-off liquid from it and 82% indicated their effluent systems allowed for the pad.
- In 2010 14% of respondents had a stand-off pad, with 47% of these having some form of sub-surface drainage in place.
- 5% (n=18) had a wintering pad

Stand-off pads, primarily using log peelings or sawdust are used more widely in the Hauraki plains than in other areas of the Waikato due to its low lying topography which leads to waterlogged soils prone to pugging and pasture damage (Wightman, Pers Comms). Waikato Regional Council has not undertaken any specific monitoring to determine the extent and type of wintering pad usage.

By way of comparison a study from the West Coast Region (Monaghan and Longhurst, 2007) found that 36% of surveyed farms used feed pads, 64% stand-off pads and 21% sacrifice paddocks (because some farmers used more than one type of wintering system, the percentage values exceed 100%). This high level of pads systems use reflects the high rainfall and heavy soils which characterise the West Coast. Without available data it would still be reasonable to assume that the levels of pad usage in low lying poorly drained areas such as the Hauraki Plains were higher than the region Waikato figures presented in the national survey[2].

[3] AgReseach recently completed their second 'State & Change 2008-2010 – A regional analysis of NZ dairy farmers' environmental management practices' study for the dairy industry (funded through Pastoral21 programme; 1st report was in 2008).

2 Contaminant Losses from Pad Systems – Review of Literature

Potential effects of wintering systems

The use of forage crops on wintering blocks has been directly linked to poor catchment water quality in New Zealand (e.g. Monaghan et al., 2004) but runoff and leaching from stand-off and wintering pads has not been extensively studied. There is however, evidence that feedlots are a major waterway polluter in the USA (e.g. Sweeton, 1988) which has prompted regulation of feedlot operations. A number of studies show that effluent draining from stand-off and wintering pads is potentially highly polluting to ground and surface water (Smith et al., 2010). Factors such as stocking intensity, type of bed material and bed depth appear to influence the concentration of pollutants in drainage but by no means eliminate its polluting potential (Luo et al., 2006; Luo et al., 2008; Smith et al., 2010).

Table 1 is a summary of published contaminant loadings onto different wintering systems. Where stocking density has been discussed in the available literature these figures are included in the table.

Table 2 is a summary of contaminant losses, via leachate and runoff, from different wintering systems. There has been no available research on contaminant loss from sacrifice paddocks or other ad hoc wintering systems such as the use of laneways/races as stand-off areas. Forage crops have been used as an alternative example given that the effects of unrestricted grazing of a crop is likely to be similar to that of a sacrifice paddock (although forage crops have higher base levels of mineral N in the soil, pugging and the deposition of large amounts of dung and urine onto the grazed are also problematic (McDowell et al., 2005; Monaghan et al., 2007)).

Table 1: Contaminant Loading on Pads - Estimates of total nitrogen (TN), total phosphorus (TP) and *E. coli* loadings to various pad systems. Figures reflect typical stocking rate and over-wintering time for respective countries unless otherwise stated.

Type	m^2/head	TN (kg/ha pasture/yr)	TP (kg/ha pasture/yr)	*E. coli* (cfu/ha pad/yr)	Reference
Stand-off (20 hrs) – NZ	10			6×10^{13}	Wilcock (2006)
Feed pad (2 hrs/10 days) – NZ	3.5			1×10^{13}	Wilcock (2006)
Feed pad (12 hrs/10 days) – NZ	6			3×10^{12}	Wilcock (2006)
Pad loading – NZ (12hr/day 2-3 months)	6-7			7×10^{13}	Wilcock (2006)
Stand-off pad (18hrs) – NZ Crushed bark[a] and sawdust[b]	14	74		1.1×10^{14} [a&b]	Luo et al. (2008) (Expmt pad)

Table 2: Contaminant Losses - Estimates of total nitrogen (TN), total phosphorus (TP) and *E. coli* losses from various pad systems.

Type	m^2/head	TN (kg/ha pasture/yr)	TP (kg/ha pasture/yr)	*E. coli* (cfu/ha pad/yr)	Reference
Stand-off (15 hrs) – NZ No effluent containment		2-21	0.2-1.5		Monaghan & Longhurst (2007)
Stand-off (15 hrs)– NZ Effluent contained		1-3	0.05-0.2		Monaghan & Longhurst (2007)
Feed pad (3hrs) – NZ No effluent containment		0-4	0-0.3		Monaghan & Longhurst (2007)
Feed pad (3 hrs) – NZ Effluent contained		0-1	0-0.05		Monaghan & Longhurst (2007)
Stand-off pad (18hrs) – NZ Crushed bark[a] and sawdust[b]	14	3.1 [a] 3.3 [b]		1.1×10^{13} [a] 3.2×10^{11} [b]	Luo et al. (2006) (Experimental pad)
Herd home – NZ Good effluent system		0-2.0	0-0.15		Monaghan & Longhurst (2007)
Tunnel house – NZ Good effluent system		0-1.5	0-0.1		Monaghan & Longhurst (2007)
Forage crop – NZ		5-20	0.1-0.3		Monaghan & Longhurst (2007)
	Note Monaghan & Longhurst (2007) report OVERSEER™ [4] estimates based on system assessments rather than actual drainage measurements. The authors state that the assessed systems contrasted greatly, especially the use of forage crops.				

Table 3 is a summary of information provided in recent literature on the efficiency of contaminant removal. These results are all from pads using woodchip, bark or sawdust as an absorbent material on the surface. These results indicate that such materials can remove significant amounts of contaminant. There is little discussion in the literature on total adsorption capacity of different material. It is expected that materials will be renewed when they become broken down or at least annually. It is noted (Smith et al., 2010) that as material break down occurs as a result of trampling it tends to clog more readily and produce increased run-off. The contaminant removal efficiency of soft material for pads under different stocking densities does not seem to have been fully researched.

[4] OVERSEER™ is an agricultural management tool which assists farmers and their advisers to examine nutrient use and movements within a farm to optimize production and environmental outcomes (http://www.overseer.org.nz/).

Table 4 is a summary of effluent quality comparisons for run-off and leachate from 'soft surface' pad systems. Contaminant concentrations for other farm effluents are also provided for contextual comparison.

Table 3: Contaminant removal efficiency - Estimates of total nitrogen (TN), total phosphorus (TP) and *E. coli* percentage removals by various pad systems.

Type	m^2/head	TN	TP	*E. coli*	Reference
Stand-off pad (18hrs) – NZ Crushed bark[a] and sawdust[b]	14	96% [a] 95% [b]		90.2% [a] 99.7% [b]	Luo et al. (2008) (Experimental pad)
Feedpad leachate – USA		99.8%			Singh et al. (2008) (Expmt pad)
Pad drainage – SCT Woodchip	8.7-23	88-95%	85-94%		CREH (2005)
Pad drainage – ENG Woodchip (6 weeks only)		93%	98.4%		Smith et al. (2010)

Table 4: Effluent Quality - Comparisons between pad leachate and runoff, and other farm effluents.

Type	m^2/head	TN (mg/l)	TP (mg/l)	*E. coli* (cfu/100 ml)	Reference
Leachate					
Stand-off pad (18hrs) – NZ Crushed bark[a] and sawdust[b]	14	86 [a] 109 [b]		$3.2x10^{11a}$ $9.6x10^{9b}$	Luo et al. (2008) (Experimental pad)
Pad drainage – SCT Woodchip (Stocked[a], Unstocked[b])	8.7-23	213-589[a] 38-263[b]	38-247[a] 62-90[b]	$9.4x10^4$	CREH (2005)
Pad drainage – FRA Woodchip		49	35		Smith et al. (2010)
Pad drainage – ENG Woodchip (6 wks only)		903	36.3		Smith et al. (2010)
Pad drainage – UK Woodchip	14	1095	51		Dumont et al (2010) (Exp pad)
Feedpad leachate – USA Geotextile lining + gravel[a] Mud[b]		1.8-53 [a] 13-19[b]	0.56-2.6[a]	7-115	Singh et al. (2008) (Exp pad)
Pad drainage – UK	14-29	175-665	28-104		Dumont et al

Type	m^2/head	TN (mg/l)	TP (mg/l)	*E. coli* (cfu/100 ml)	Reference
Woodchip					(2010)
Runoff					
Feedlot runoff – USA		50-2,100			Fajardo et al (2001)
Feedlot runoff – Canada Barley straw or woodchip	18-28	85	35	1×10^3 – 10^7	Miller et al. (2004)
Feedpad runoff – USA Geotextile lining + gravel[a] Mud[b]		10.4-36.5[a]	0.6-4.6[a] 1.6-5.5[b]	11×10^4-168×10^4 [a] 11×10^4 [b]	Singh et al. (2008) (Exp pad)
Other Farm Effluents					
Raw Manure (urine and faeces)[5]		5100	400	2.2×10^7	
FDE		269 (181-506)	69 (21-82)	2×10^7 Ledgard et al (1996)	(Longhurst et al., 2000)
		355			(Selvarajah, 1999)
Two pond system - anaerobic		180	29		(Longhurst et al., 2000)
- aerobic		91	23		
- anaerobic slurry		1650	290		
Oxidation Pond		63.2	25.7	5.6×10^4	
Mole pipe drainage of FDE		210-270	1.4-250	7.9×10^3-1.6×10^7	(Monaghan and Smith, 2004)
Laneways Milking – near shed Winter – near shed		52.8 43.7	23.4 18.1	8.5×10^5 6.3×10^4	(Smith and Monaghan, 2009)
Milking – ~500m away Winter – ~500m away		6.8 6.6	5.7 3	1×10^5 3.2×10^3	

It is difficult to accurately determine the relative polluting potential of each type of system due to large disparities caused by differences in pad characteristics, stocking rate and time of pad usage. Nevertheless, from what information is available it appears that wintering and stand-off pads have the highest potential for N, P and faecal microbial pollution followed by forage crops, feed pads and covered systems (Table 2).

Literature shows that for ‘soft surface’ pad systems the concentration of N, P, and E. coli in runoff and leachate can vary markedly (Table 4). Due to the porous nature of most materials used it is assumed that runoff from these pad systems has received similar treatment to what is described in the literature as leachate.

In general the quality of runoff and leachate from these pad systems can be considered to be similar in character to average farm dairy effluent (CREH, 2005) (see Table 4).

[5] Based on excretion of 55 l/cow/day and assumptions in Table 7

Factors influencing drainage quality

Pad design, stocking density, bed material and rainfall are all factors that affect the quality of drainage effluent. Carbon based bed materials have been shown to partially treat effluent by retaining solids, adsorbing liquid, faecal microbes and digesting nutrients (Luo et al., 2008; Dumont et al., 2010; Smith et al., 2010). Carbon based materials will retain contaminant particles (charged and non-charged) and establish and maintain biofilms that are capable of N-transformation (Luo et al., 2008). Luo et al. (2006) found that loss of total excreta N from four carbon materials was greatest for wood chips (14%), followed by bark (9%), zeolite (8%) and soil (1%). Chemical analyses of the materials suggested that between 66% and 76% of applied excretal N had accumulated in zeolite, bark and soil. About 35% of applied excretal N accumulated in wood chips (Luo et al., 2006). Dumont et al. (2010) found that significant liquid retention occurred in woodchip pads although retention of effluent decreased during very wet periods. Modelling of the effects of stocking density and woodchip depth on effluent discharge was undertaken by (CREH, 2005). As expected, this showed that for a given background rainfall, increasing stocking and low thicknesses of woodchip lead to greater discharges of effluent.

Most of the research reported on woodchip pads has been based on stocking rates of 15-25m^2/cow (Table 4), and this is consistent with pad usage in the United Kingdom (Figure 5). However, feed and standoff pad design in New Zealand recommends smaller areas per cow (short term use of +12 hrs/day up to 2 days in a row – 3.5 m^2/cow, long term use of +12 hrs/day for 3 days or more in a row – 5.0m^2/cow, permanent with no off grazing – 8m^2/cow + 1m^2/cow feed area, Crops or sacrifice paddock 8.0m^2/cow (DEXCEL, 2005)). The depth of soft material recommended in New Zealand is 500-1000mm (DEXCEL, 2005) and most research in literature has investigated depths at the top end of this recommendation (Luo et al., 2008). Therefore, in evaluating the potential implications of drainage from these pad systems it is important to consider the effects of higher stocking rates and moderate thicknesses of bedding material.

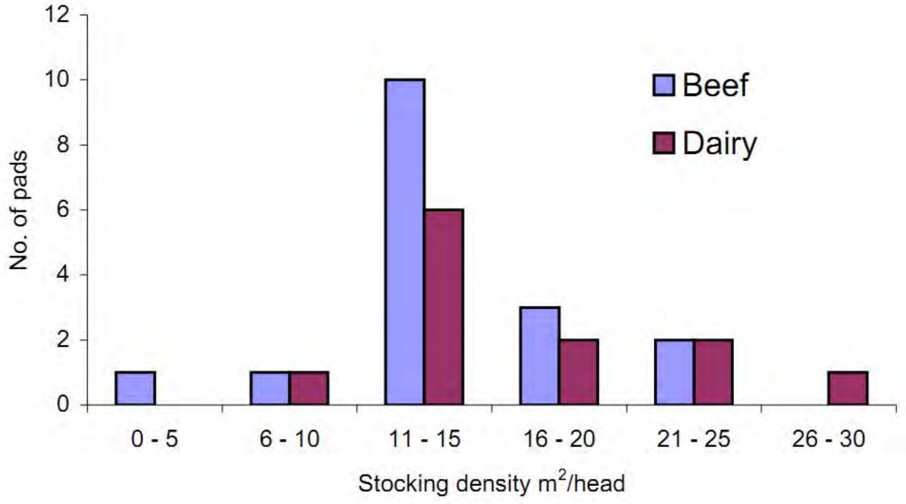

Figure 5: Stocking densities recorded on woodchip pads in England and Wales (Smith et al., 2010)

While soil is clearly effective when it is structurally sound, it is not recommended for wintering or stand-off pads because it is prone to compaction and subsequent loss of porosity (Smith et al., 2010). Crushed pine bark and sawdust have large total surface areas and cation exchange capacities and can be used for long periods without maintenance (Luo et al., 2008). Sawdust has the largest surface area and the best retention of microbes but may cause the pad to 'seal' and become ineffective (Luo et al., 2008; Smith et al., 2010). Gravel and sand provide no treatment of effluent but will facilitate the drainage of effluent from the pad surface and are easy to clean (DEXCEL, 2005; DEC, 2006).

3 Risk Assessment of Pad Systems

3.1 Using a Risk Management Approach

One of the aims of this report is to provide direction to field staff when assessing feed pad rules. This assessment of feed and standoff pads requires both assessing the compliance of current activities and looking for indicators of risk of future non-compliance.

For the purposes of this report, the focus will primarily be on risk assessment. Risk assessment is a systematic assessment of the potential adverse effects of contaminants on plants, animals, or ecosystem integrity. Risk assessment lies at the heart of risk management because it assists in providing the information required to respond to a potential risk. Risk assessment essentially asks the question:

'How likely is it that damage will be or has been done by contaminants?'

<u>The Nature of Risk</u>

While we can assess and estimate risk at a certain point in time we cannot measure it in the present because of the uncertainty associated with both the probabilities of an occurrence and the potential outcomes. Risk cannot be measured until after events have happened. These uncertainties force the decision maker to deal with many aspects of risk assessment using subjective rather than objective methods (Pyle and Gough, 1991).

Risk (encompassing environmental risk) has three basic elements:

- an action which leads to,
- events that have a probability of occurrence,
- these events are associated with outcomes, which are often expressed in terms like 'magnitude', 'consequence', 'severity' or 'significance'.

Risk is about understanding the probability of an outcome and the magnitude of the outcome. Similar outcomes with similar probabilities may have different magnitudes depending on environmental factors. Outcomes cannot be predicted in the face of uncertainty, so value judgements need to be made about outcomes in uncertain situations. When uncertainty is present there can be no 'objectivity' when assessing risk (Pyle and Gough, 1991).

Assessment of Risk

Most situations involving risk require the decision maker to make value judgements about the particular situation. Situations involving risk are often unique in terms of their physical, social and technical factors and there are often site-specific uncertainties. There are some general principles for environmental risk assessment that can be followed.

Environmental risk analysis is often less certain than risk analysis used in some other disciplines. There are a number of reasons for this:

- The complexity of environmental systems mean they are often not well understood so the consequences of a pollutant can be difficult to determine.
- Environmental systems are often highly variable. Expert opinion is likely to consist of a range of possible outcomes. Even if measurements of consequence and likelihood are made, the statistical certainty of these will often be low.
- There is often a lack of reliable data about consequences of a pollutant in the environment under consideration. While we can extrapolate from studies of similar systems, no two receiving environments will be the same. This may lead to unexpected outcomes.
- The long time scale that environmental impacts occur over can make prediction of future states very difficult. Some actions may not impact upon the environment until sometime in the future. (EPA, 2007).

There are three main parts to the risk assessment process (Figure 6). These interact to some extent and tend to overlap. They are:

1. Risk Identification - identifying actions and outcomes/events,
2. Risk Estimation - estimating probabilities and magnitudes,
3. Risk Evaluation – determining the level of acceptability for risk and making decisions accordingly.

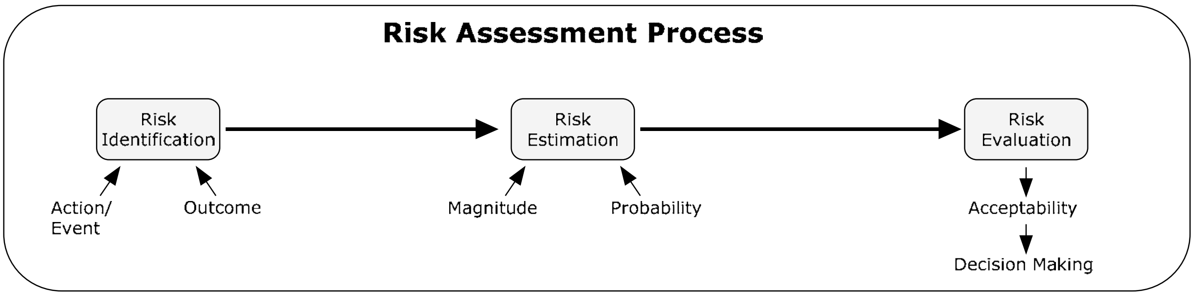

Figure 6: Steps in the risk assessment process

Risk analysis provides a structured and systematic process that makes the best use of available information for making decisions about environmental issues. Determining an acceptable environmental risk is concerned with safety of ecological and social values. Currently, the setting of an acceptable risk is seen as a process that involves members of the community and agencies affected by a decision, both indirectly and directly, such as occur in regional plan development when rules and conditions are defined. Another layer of detail on what is acceptable is defined through development of environmental case law.

3.2 Risk Assessment within a Farm Systems

3.2.1 Farm Scale Contaminant Losses

Dairy farms are intensive land use systems and are known to be “leaky” for N, but they are also significant contributors of P and E. coli. For context in the discussion on contaminant losses from pads systems Table 5 and Table 6 provide estimates of whole farm and specific activity losses of contaminants respectively.

Table 5: Whole farm losses of total nitrogen (TN), total phosphorus (TP).

Type	TN	TP	Reference
Whole farm losses (kg/ha/yr)			
Average dairy farm loss	40	0.5-1	Menneer et al. (2004)
OVERSEER – range over 4 study farms	25-52	0.4-1.4	Monaghan et al. (2008)
Average dairy farm loss	30-45		Burgess (2003)
OVERSEER - 3 farms	18-41	1	Power et al. (2002)
OVERSEER - 10 farms	30-52	0.2-1.8	Judge et al. (2004)

Table 6: Farm scale contaminant losses

Farm Activity	Contaminant Losses		
	Nitrogen (kg/ha pasture/yr)	**Phosphorus** (kg/ha pasture/yr)	**E.Coli** (E coli/ha pasture/yr)
Farm Pasture		0.34* (mole drain)	1x10^{11} #
	30**	0.1**	
0kgN/ha/yr	30 (12-74)*		
400kg N/ha/yr	130 (109-147)*		
Farm Dairy Effluent			(Load to shed 1 x 10^{11}#)
Oxidation pond discharge			1.6x10^{10}#
Irrigated area	54-116** (/ha irrig.)		Raw: 1x10^{12} # (/ha irrigated)
	150*** (/ha irrigated)	1.6** (/ha irrigated)	Pond: 8x10^{11} # (/ha irrigated)
		0.86* (mole drain)	
Crop Grazing	5-20*	0.1-0.3*	
Feed pad (no effluent containment)	0-4*	0-0.3*	
Standoff pad	2-21*	0.2-1.5*	

Farm Activity	Contaminant Losses		
	Nitrogen (kg/ha pasture/yr)	**Phosphorus** (kg/ha pasture/yr)	**E.Coli** (E coli/ha pasture/yr)
(no effluent containment)			
Stock in Streams (unimpeded access)	0.22[6]		6.6×10^{9} #
Stream Crossing (4 crossings/day, 250 cows)	0.65[7]		3×10^{10} #
Laneways (Normal use)	3-4%^ (%of whole farm discharge)	3-28%^	4.5×10^{10} # 3-12%^

(Wilcock, 2006)
* (Monaghan and Longhurst, 2007; Monaghan, 2008)
** (Burgess, 2003)
*** (Houlbrooke et al., 2004)(annual inputs of 1125kg N/ha, 125 kg P/ha – these trials were carried out under conditions representing 'poor practice')
^ (Smith and Monaghan, 2009) (results based on range from best case where 5% of farm laneways discharge to water, to 100% discharging to water)

The relative contributions of farm activities to catchment E. coli loads is summarised in Figure 7.

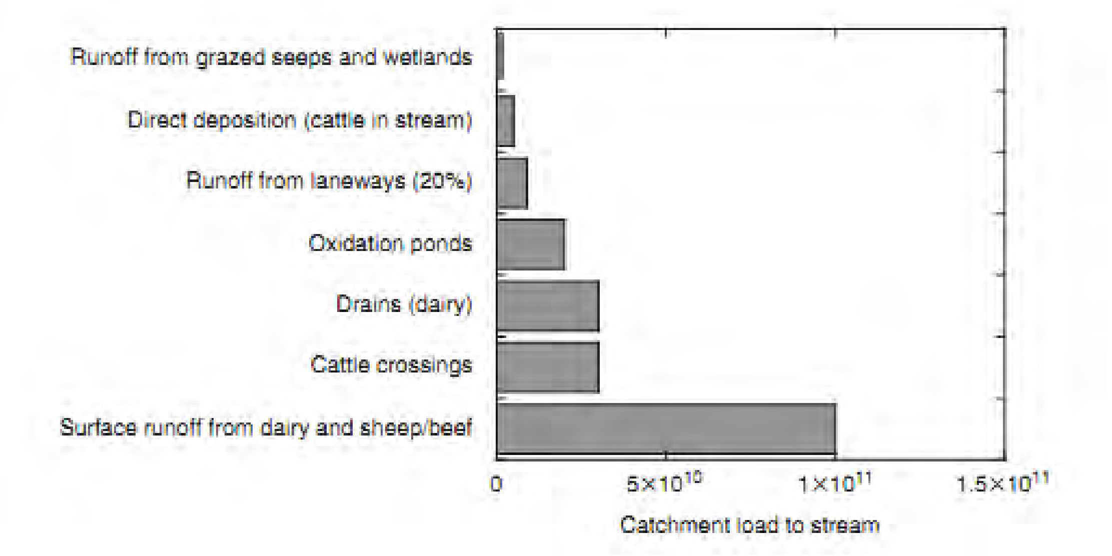

Figure 7: Catchment E. coli loads to stream (Wilcock 2006)

Catchment scale losses from dairy farming have recently been studied across the country under the best practice for dairy catchments project which has looked at the effects of best practice on catchment nutrient loads (Monaghan et al., 2008)). A summary of catchment scale estimates of contaminant losses is provided in Table 7.

[6] Based on 20g N/cow/day, 3 cows/ha and 1% of defecation in stream(Wilcock, 2006)
[7] Based on 20g N/cow/day, 3 cows/ha and 3.6% of defecation in stream (Wilcock, 2006)

Table 7: Catchment scale estimates of contaminant losses

Contaminant Losses			Reference
Nitrogen (kg/ha pasture/yr)	**Phosphorus** (kg/ha pasture/yr)		
35	1.16		(Wilcock et al 1999)
	0.81-0.92		(Monaghan and Longhurst, 2007)
32	1.41	Toenepi	(Monaghan et al., 2008)
48	0.39	Waiokura	
52	1.25	Waikakahi	
30	0.94	Bog Burn	

This data provided in Table 7 gives context for assessing the relative risk and consequences of contaminant loss from pad systems which is undertaken in Section 3.3.

3.2.2 Benefits of wintering systems

Contaminant loss from pad systems can have a net beneficial outcome for the level of contaminant loss from other part of the farm (Christensen et al., 2011). This needs to be accounted for in the assessment of potential effect as although losses form a pad system should be managed to BMP, the consequence of minor losses is still likely to be a net environmental benefit for their use.

Annual N losses from farms can be significantly reduced by using pad systems. Removing animals from pasture onto a pad between autumn and calving (c. 4 months) can reduce farm N loss by 60% (Monaghan et al., 2007). A 27 % reduction of farm nitrate leaching was achieved by keeping cows off pasture and using a stand-off pad for the herd every night from May to August (de Wolde, 2006), a 25% reduction using a stand-off pad 18 hours per day from mid-May to early July (Ledgard et al., 2006) and a 40% reduction has been achieved by standing cattle off during autumn (Sonthi, 2010). These results indicate that grazing of pasture during the wettest times of the year contributes between 27% and 60% of farm N loss.

Winter trampling and overland flow is a key source of P and sediment loss but the relative contribution of normal winter grazing to whole system loss of these contaminants is not well known (Monaghan, 2008; Curran-Cournane, 2010). P loss over the winter period equals or exceeds loss for the rest of the year in Southland catchments where many farms rely on forage crops (McDowell et al., 2005; McDowell et al., 2008). Unfenced waterways are also known to be large contributor of catchment scale P and sediment export (McDowell et al., 2008). Removing cattle from pasture over winter can reduce the risk of P loss but the extent of the benefit in terms of reducing P and sediment loss would vary depending on topography (e.g. less loss on rolling hill country where overland flow can still entrain loose sediment).

Measurements of storm loads of *E. coli* in Toenepi Stream, Waikato, revealed that 6.4% of the total land loading was exported to the stream, with 95% of this being produced in flood events (Wilcock, 2006). Wilcock (2006) calculates that for a total catchment area of about 1500 ha the yield of *E. coli*/ha/yr from flatland dairy farms to water is around 10^{11}. Assuming that land loading is mostly to pasture, and the majority of flood events occur during the winter grazing period, it is safe to presume that the bulk of E. coli loading to water is derived from winter grazing. The use of wintering systems would provide a reduction in this available load if the accumulated effluent is well managed.

The benefits for contaminant loss offered by pad systems are driven by less urine patches on wet soils and less contaminant loads in runoff from saturated or disturbed soils. These benefits can however be reduced if the accumulated effluent from a pad systems is not managed with the same attention that is required of the farm dairy effluent.

3.3 Risk Assessment within a Feed and Standoff Systems

The risk assessment in this section is focused only on pad systems that are **not actively managing their effluent**. It is these systems that can result in uncontrolled surface runoff of effluent into drains and waterways or create significant ponding and discharge to groundwater (Figure 8).

Figure 8: Effluent Runoff from pad creating ponding or discharge into drains

Unmanaged effluent can leave these pads as either run-off or leaching. The run-off that ponds can then either leach to groundwater or run-off into the drainage network at a later time following more rainfall. The process for assessing the different elements of risk is shown in Figure 9. The benefits for contaminant loss that occur as a result of pad usage are discussed in Section 3.2.2. The assessment of risk for these outcomes for surface water and groundwater are discussed in the following parts of Section 3.3. The management of solids from the surface of these pads is also an issue requiring effective management. This is discussed further in Section 3.3.5.

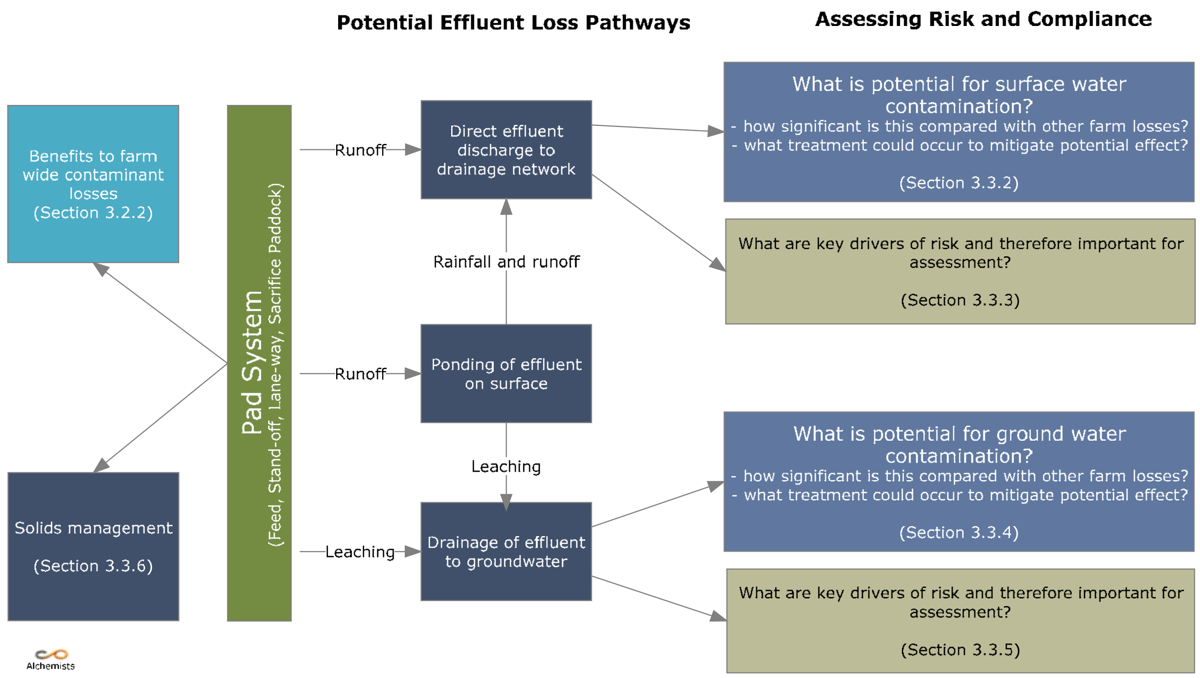

Figure 9: Process for assessing the elements of risk from effluent losses from pad systems

3.3.1 Potential Effluent Quality and Loads

Assessment of the potential impact of pad systems is not simple as not only are there different types of pad set-ups, there is also a range of management practices used and site variables that can influence the effluent quality and quantify. These include:

- Stock age/type
- Stock density
- Feed types – quality and quantity
- Pad surface material (saw dust, bark, soil, sand, soft rock)
- Pad cleaning (scraping/washing, renewal of surface material)
- Management of accumulated effluent solids
- Rainfall

A comparative analysis of contaminant loads onto different systems is presented in Table 8 This analysis requires that a number of assumptions are made in order to provide relative comparisons. These assumptions are outlined at the bottom of Table 8 and need to be taken into account with the estimates provided.

Table 8: Estimates of potential contaminant loads to pads systems

	m^2/cow	Time defecating on Pad	Pad Area* (ha)	Nitrogen				E.coli
				N load to pad (kg/day)	**N** load to pad (kg/ha pad/day)	Annual **N** load to pad (kg)	Annual N load normalised (kg/ha pasture/yr)	**E.coli** (E. coli /day)
Stand-off Pad (18 hours on/ 6 hours grazing)	5 m^2	10 hrs	0.165	58	350	5300	48	7.5 x 10^8
Feed Pad or Laneway (4 hour/day)	3.5 m^2	4 hrs	0.116	23	200	2100	19	3 x 10^8
Wintering system (24 hr/day)	15 m^2	16 hrs	0.495	92	187	8500	77	1.2 x 10^9
Sacrifice Paddock	8 m^2	10 hrs	0.264	58	220	5300	48	7.5 x 10^8
Forage crop	8 m^2	16 hrs	0.264	92	350	8500	77	1.2 x 10^9

	m^2/cow	Time defecating on Pad	Pad Area* (ha)	Phosphorus				
				P load to pad (kg/day)	**P** load to pad (kg/ha pad/day)	Annual **P** load to pad (kg)	Annual **P** load normalised (kg/ha pasture/yr)	Possible Effluent Volume (m^3)
Stand-off Pad (18 hours on/ 6 hours grazing)	5 m^2	10 hrs	0.165	4.6	28	423	3.8	810
Feed Pad or Laneway (4 hour/day)	3.5 m^2	4 hrs	0.116	1.85	16	170	1.5	454
Wintering system (24 hr/day)	15 m^2	16 hrs	0.495	7.4	15	680	6.2	1895
Sacrifice Paddock (6 hr/day grazing elsewhere)	8 m^2	10 hrs	0.264	4.8	18	423	3.8	1293
Forage crop	8 m^2	16 hrs	0.264	7.4	28	680	6.2	1293

* m^2/cow x herd size (330)

The following assumptions are used in preparing the estimates presented in Table 8:

- Cows are active for 16 hours of the day and they will defecate evenly during this time (DEXCEL, 2005) – it is assumed that they are asleep for 8 hours/day on the pad.
- Stocking rate of 3 cows/ha on an effective area of 110ha, herd size of 330

- N loading in defecation is based on urine load (10 urination/day, 2 l/urination, 10 g N/l = 200g N/cow/day (Haynes and Williams, 1993)) and faeces load (0.8g N/100g dry matter feed, and given 10kg feed/day = 80g N/cow/day (Haynes and Williams, 1993)) [Total N discharge of 280g /cow/day ~= 17.5g N/cow/hour] Note – these loads can vary depending on the amount and type of feed a cow receives.
- P load in defecation of 22g P/cow/day is used based on (Monaghan et al., 2007), and estimates of 10-23g P/cow/day in faeces and 4g P/cow/day in urine (Haynes and Williams, 1993)
- E.coli loading of 1.2 x 10^9 E.coli/cow/day (7.5 x 10^7 E.coli/cow/hour) is used (Wilcock, 2006)
- Areas per head are based on (DEXCEL, 2005)
- Use of the pad is assumed at three months/year (92 days – Jun, Jul, Aug))
- Potential effluent volume is calculated based on the rainfall and urine inputs. Net rainfall for the 3 month period is 260mm (300mm rainfall less 40mm evaporation – based on Ruakura met station data and comparable to (Luo et al., 2008) and urine input of 20l/cow/day.

The data in Table 8 indicates that potential outputs from different pads assuming the effluent had not received any treatment (i.e. straight effluent run-off) for a sealed pad with no cover of absorbent material. This analysis provides an indication of the relative risk between pads and a potential maximum risk the contaminant losses.

It is recognised that the way pad systems are used can vary widely depending on the farm system and weather conditions. The examples presented in Table 8 represent high pad usage (i.e. continuous use for 3 months) compared with what might occur in many parts of the Waikato, but the stocking densities (area per head) are New Zealand recommended values that are higher than those reported in the literature case studies. Stocking density can strongly influence effluent loading rate to pad, drainage volumes and contaminant concentrations (Smith et al., 2010).

Woodchip, bark and sawdust are mainly used as adsorbent carbon rich material for pads. These materials can retain high levels of ammonia, P and faecal microbes thereby providing good levels of treatment. Soil has also been trialled as a medium and provides very good treatment performance (Luo, Donnison et al. 2006) but its permeability could limit its usefulness (Vinten et al., 2006).

The ability of soft pad material to adsorb the moisture from the effluent and thereby reduce drainage has not been specifically addressed in the literature reviewed. The results from (Luo et al., 2008) indicates that there is very little water absorption from bark or saw dust. The study reported in this paper that the drainage captured equates closely to the rainfall and urine input to the pad. This may be a result of rainfall wetting at the pad before use and if so this outcome is still representative of actual farm practice.

The location of wintering pads areas must also be taken into account as with these estimates the polluting potential of a poorly managed pad or sacrifice paddock will depend somewhat on soil type, rainfall and the proximity of the pad or sacrifice paddock to drains, aquifers and surface waterways (Monaghan and Longhurst, 2007).

A review of woodchip corrals (pads) in the UK (Edwards et al, 2003) concluded that there are significant pollution risks from the transport of leachate containing ammonia, faecal pathogens, nitrate and phosphates to surface and groundwaters. In the context of this report these risks to surface and groundwater are discussed further in Sections.3.3.2 – 3.3.5.

3.3.2 Potential for Surface Water Contamination

Bare Hard Surfaces – Feed Pads, Rock Covered Standoff Pads, Land Ways

Hard surface pads include concrete or compacted rock feed pads, sections of laneway used as stand-off areas, or stand-off pads which have hard or low permeability surfaces such as compacted rock. The risk of surface water contamination from such hard surfaces which do not capture and manage the generated effluent is high as effluent can accumulate and will run off in high concentrations without any significant treatment. Concentrations of contaminant in run-off would be in excess of those reported in the literature for drainage or run-off from woodchip covered pads. Such surfaces could in theory contribute a significant proportion of farm nutrient losses (Table 8). The runoff contaminant concentrations could be somewhere between raw effluent and farm dairy effluent (Table 4).

The risk of surface water contamination from pad systems is by either direct run-off of effluent into water or run-off that ponds adjacent to or near a pad and is then flushed into a waterway during further rainfall. The concentrating effect of hard surfaces on rainfall means the likelihood of significant volumes of run-off being generated is high. Also these with these hard surfaces there is minimal opportunity for any treatment or remediation.

Discharges of effluent run-off of this kind can receive some remediation in the drains and small streams on a farm through sedimentation, uptake and die-off. But the volume and concentration would still likely create significant impacts on downstream water bodies. It should also be noted that because pasture and wetland plants, streams and drain sediments act as sinks for the P and faecal matter during relatively low flow conditions the faecal and P concentrations of pastoral streams can often be modest. However during larger flood events the faecal material can be flushed out of wetlands and stream sediments producing high loads of faecal microbes when combined with wash off from the land (Wilcock, 2006).

Even shallow ponding or deposition of effluent into ephemeral drainage networks can create future risk of contamination. Donnison and Ross (2009) suggest that rainfall will transfer faecal microbes from these soils bordering streams to the water for at least 28 days after the deposition.

Hard Surfaces with Absorbent Material – Standoff Pads

Standoff pads built with a hard surface and covered with soft material can provide significant levels of treatment to the effluent as long as this covering material is a high carbon substrate such as bark or woodchips (see Table 3). However, literature would indicate that the quality of effluent run-off from these systems has a similar quality to FDE and therefore it still has the potential to pollute surface waters.

If these pads are poorly sealed there is a risk of high contaminant loads leaching into groundwater (see section 3.3.4). This then impact on small surface water streams located in close proximity to pads.

The risk of pollution from contaminant run-off would be expected to increase over time as the cover material becomes saturated. Pad systems with absorbent material are often used continuously for extended periods and hence have higher loadings than pads that may be used more intermittently.

If pads are well managed (stock density of ~15m^2/head and at least 1m depth of absorbent material) an expected 85 to 95% removal of contaminant can be achieved (Table 3) and the risk from potential contaminant loads (Table 8) could be significantly reduced.

Soil Surfaces – Sacrifice Paddocks and Forage Crops

Where pads are created using an area of paddock, high levels of effluent is then deposited directly onto the soil profile. The soil on these pads becomes highly disturbed due to weakness and high stock density. This leads to pugged and compacted soils with reduced permeability and elevated fertility. Run-off is more likely to be generated from these areas than undisturbed paddock creating an increased risk of contaminant and sediment run-off and the waterways.

The extent of risk will depend on the size of pad area, its use and its proximity to waterways.

3.3.3 Runoff Risk – Key Drivers

The key drivers from run-off are site characteristics and those factors which influence effluent volume and quality. These are:

<u>Effluent Volume:</u>

- Pad area
- Herd size
- Stock density
- Time on pad
- Surface material
- Pad permeability
- Presence of ponded effluent
- Rainfall (not controllable)

<u>Effluent Quality</u>

- Stock density
- Time on pad
- Length of use
- Surface cover material – type, thickness, quality (how degraded/saturated)

<u>Site Characteristics</u>

- Pad slope

- Surrounding topography
- Distance to drainage network/streams
- Sensitivity of receiving environment

3.3.4 Potential for Ground Water Contamination

Permeable Surfaces with Absorbent Material – Standoff Pads

Pads which do not have a sealed base can allow drainage from the overlying absorbent material to leach downward directly into the underlying groundwater. Run-off from these pads can still occur during high levels of drainage.

This pollution risk of this leaching is influenced by a range of processes that can occur under a freely draining pad as illustrated in Figure 10. These processes drive the quality of effluent and are influenced by the type and quality of absorbent material.

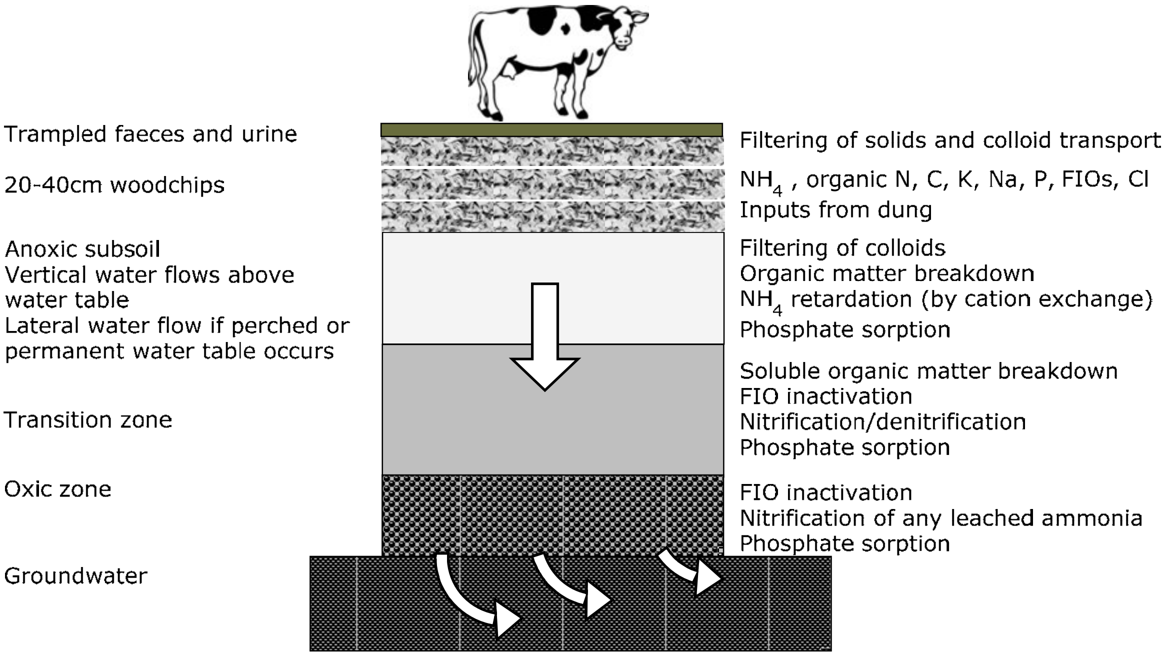

Figure 10: Processes occurring under a freely draining feed or standoff pad - after (Vinten et al., 2006) (FIO – faecal indicator organisms)

The potential for groundwater contamination will be relative to the volume and strength of effluent drainage that leaches into the soil profile. The volume will be influenced by soil type (i.e. higher drainage could occur on a pumice or peat subsoil then from a clay subsoil). The strength of effluent will depend on the type of cover material, intensity of use and dilution by rainfall.

The use of non-carbon materials and the absorbent cover (i.e. sand or pumice/soft rock) would provide much less treatment of effluent and result in much higher concentrations of contaminant in the leachate. There are a wide range of processes that can occur in the soil, unsaturated zone and saturated zone to attenuate contaminants as they leach and move into the groundwater system (Figure 11). Many of these are site-specific so it is difficult to generalise outcomes and formulate a regional context.

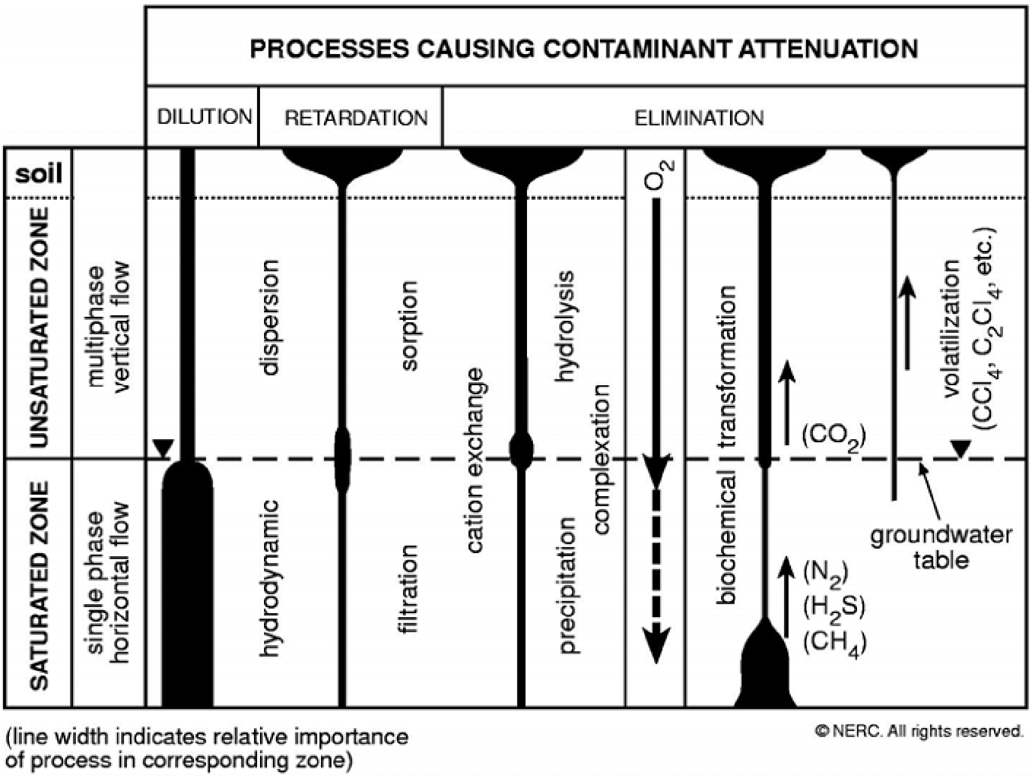

Figure 11: Processes promoting contaminant attenuation in groundwater systems (Morris, 2010)

Preferential flow has been identified as an issue for poor treatment of irrigated FDE (Burgess, 2003; Houlbrooke et al., 2010). The saturated conditions that can occur under these sorts of pads and sacrifice paddocks are also likely to lead to preferential flow, potentially increasing the loads of contaminants to groundwater. Preferential flow has been found to increase P losses from FDE application (Houlbrooke et al., 2010). This is also likely to occur with leaching losses from pad systems. In allophanic soils adsorption of P is likely to be high reducing the risk of P losses off site. This is unlikely to be the case in peat soils with their low cation exchange capacity and therefore increases the risk of P loss.

The loss of N to groundwater can be high as a result of leaching. Overseas investigations into nitrate leaching underneath stand-off pads indicates that high levels of leaching can occur (114-566 kg/ha/yr) (Vinten et al., 2006). There are no New Zealand examples of nitrate levels under pad systems in the available literature. The potential for N losses from standoff pads have been estimated at 2-21 kg N/ha pasture/yr (Monaghan and Longhurst, 2007). The calculations and assumptions in Table 8 are consistent with this providing an estimate of loss of 2.4-7 kg N/ha pasture/yr[8]. If most of the drainage from a pad leached into groundwater beneath the pad this could represent a significant "point source" of N loading, estimated in the order of 1600-4800 kg N/ha pad/yr (based on Table 8 stand-off pad calculations[6]).

[8] Estimated N load to pad of 5300 kg/yr, assuming 85 to 95% N removal by absorbent material, expect 265-795 kg N/yr in drainage.

The high concentration of E.coli in the drainage and the associated risk of preferential flow could also represent a significant "point source" risk underneath a pad or from areas where effluent ponding from pad run-off has occurred.

Hard Surfaces with Absorbent Material – Standoff Pads

The risk to groundwater from these hard surfaces with absorbent material is also from ponded effluent runoff which can then leach through the soil profile into groundwater. Run-off from these pads is a similar risk to FDE ponding and leaching to groundwater. The potential impact depends on the volume of effluent leaching, depth to groundwater and sensitivity of downstream receiving environment.

See discussion under Permeable Surfaces above for further assessment of potential impacts.

Bare Hard Surfaces – Feed pads, Rock Covered Standoff Pads, Land Ways

The risk to groundwater from bare hard surfaces is from ponding of effluent run-off. This can then leach through the soil profile into groundwater. Run-off from these pads can pose a high risk because of the potential volume and concentration of effluent that can be discharged.

See discussion under Permeable Surfaces above for further assessment of potential impacts.

Soil Surfaces – Sacrifice Paddocks and Forage Crops

Concentrated input of excrement into a paddock area could represent a significant risk for groundwater contamination. Putting aside the risks from run-off and overland flow, high contaminant loads onto the soil will be available for leaching or preferential flow down through the soil profile. These risks are similar to those described above with regard to permeable surfaces.

The additional risk with sacrifice paddocks is that there is no carbon-based absorbent material to assist in contaminant capture and treatment. Even assuming urea applied to the paddock would have high losses through ammonia volatilisation (~40% losses (Luo et al., 2006)) the potential nitrogen available for leaching could be up to 34 kg N/ha pasture/yr (based on Table 8 stand-off pad calculations). Such an outcome could easily offset any benefits for N losses of using a standoff paddock (assuming average farm losses of 45 kg N/ha/yr and a 40% reduction due to use of a standoff pad = 18kg N/ha/yr the potential losses could represent a 16 kg N/ha/yr increase in losses from the whole farm).

3.3.5 Leaching Risk – Key Drivers

The key drivers for leaching are site characteristics and those factors which influence effluent volume and quality. These are:

Effluent Volume:

- Pad area
- Herd size
- Stock density
- Time on pad
- Surface material
- Pad permeability
- Presence of ponded effluent
- Rainfall (not controllable)

Effluent Quality

- Stock density
- Time on pad
- Length of use with
- Surface cover material – type, thickness, quality (how degraded/saturated)
- Management of used solids

Site Characteristics

- Permeability of pad surface
- Permeability of sub-soil
- Depth to groundwater
- Type of subsoil
- Distance to drainage network/streams
- Sensitivity of receiving environment

3.3.6 Solids Management

Solids are the material which is either scraped off hard surface pads or the absorbent carbon material which is being used to retain effluent on the pads. These solids need to be managed to minimise the risk of contaminant loss to the environment. Sufficient time should be allowed for pathogens to die off to low levels prior to the land disposal of spent pad material. Storage for at least six months or under conditions that promote composting are recommended (Luo et al., 2008). An associated risk with this storage is an increase in ammonia losses and potential for increases in greenhouse gas losses.

If the solids are left on the pad they can represent an on-going source of high contaminant inputs to the environment. The storage and spreading of these solids needs to be undertaken to minimise risk and should be managed with farm dairy effluent solids/sludge's.

3.3.7 *Summary of Potential Contaminant Losses*

This section summarises the potential contaminant losses from different pad systems and how these can alter the total farm losses.

Potential losses can vary widely depending on the pad type, its construction and use, animal management and feed types, and weather conditions. Estimates used here are based on a range of assumptions used in the calculations (see Table 8).

The losses of N in drainage effluent and runoff from a poorly constructed and managed stand-off pad can represent a significant portion of the annual losses from a farm. Figure 12 shows how the potential benefits from stand-off pad use (40% less loss) can be reduced by about a third if the effluent drainage is not managed correctly. Stand-off pads with no effluent management could potentially increase whole farm losses by up to 35%

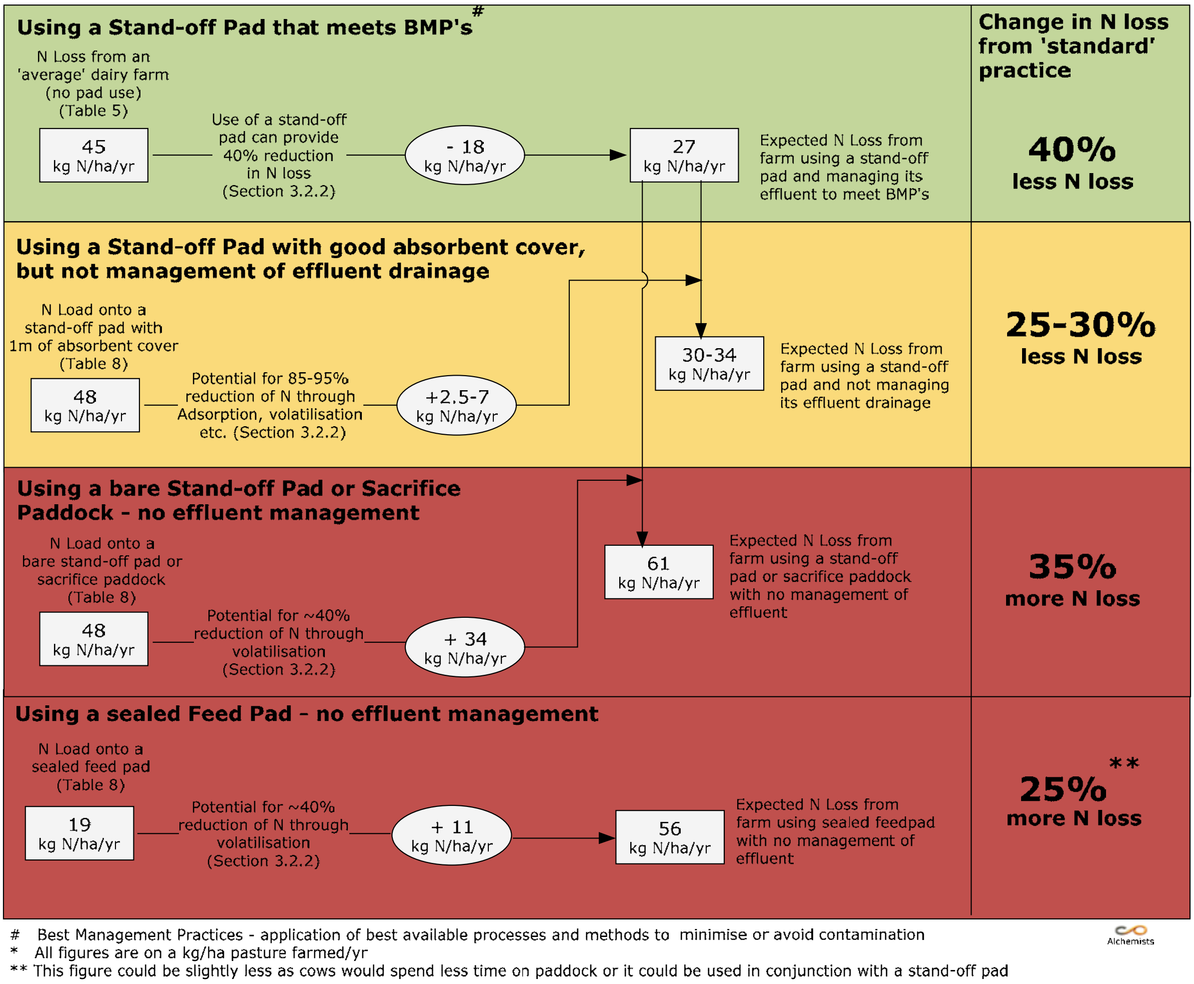

Figure 12: Relative effect of different stand–off pad management on Farm scale N losses

The potential losses from a feed pad are less (~40% of a stand-off pad loads) as the animals spend less time on these systems. Feed pads could still potentially add significantly to total farm losses if effluent runoff is not managed (up to 25% more N loss from a farm - Figure 12).

The losses of N from unmanaged feed and stand-off pads can represent significant point sources for pollution, with annual N loads onto these pads in the order of 2100-5300kg/yr. This could potentially result in 1260-3180 kg N (based on assumption of ~40% loss by volatilisation) being lost into a small area of the farm (01.- 0.2 ha). The proximity of these systems to small or sensitive water bodies is therefore very important

Losses of P from pads and their potential contribution to total farm losses are difficult to quantify due to the different transport and removal mechanisms for P. P is readily absorbed to soil particles and therefore high levels of loss to groundwater are unlikely in the absence of large scale preferential flow. P losses from sealed pads direct to the waterways could represent a substantial increase in whole farm losses. Potentially P losses in the effluent drainage from a sealed pad with an absorbent cover of bark could result in up to a 40% increase in P loss from a farm if the drainage discharged into a waterway (Table 9).

Source	P loss (kg/ha pasture/yr)	P loss (kg/ha pasture/yr)
'Average' farm losses (Table 5)	0.9 (0.4 – 1.4)	~ 40% increase in P loss (Potential increase from sealed stand-off pad no treatment of drainage)
Bare sealed Stand-off Pad (Table 8)	3.8	↑ 0.4 (0.2-0.6) Pad with 1m of absorbent material (therefore 85-95% removal) –
Sealed Feed Pad (Table 8)	1.5	

Table 9: Relative P losses from farm and pads systems

Research on the losses of E.coli from feed and stand-off pads and associated impacts is limited. The data in Tables 1, 2, 6, and 8 would indicate that these pad systems can generate high E.coli loads, which can be in excess of loads from other farm practices.

The quality of effluent from pads systems could be expected to range from raw effluent off bare sealed pads similar to FDE quality from pads with a suitable thickness and type of covering material.

3.3.8 Summary of Environmental Risks

The potential environmental risk from pad systems can vary depending on the pad type, surface characteristics and intensity of use. The analysis provided is **only relevant to pad systems that do not follow best practice**[9] and do not actively manage the accumulated effluent from these activities.

Although it is acknowledged that the use of pad systems does have benefits for the quantum of contaminant losses from other parts of the farm, poorly managed pads run the risk of

[9] Best practice is taken to be the operation of a sealed pad which has a system to collect all the effluent drainage. This effluent is then treated to the same standard/methods as the farm dairy effluent.

over-riding these benefits and becomes a net negative impact on environment. If not managed then pads can create a significant "point source" for contaminants.

The key risks in order of relative[10] importance are overviewed.

<table>
<tr><td rowspan="3">High</td><td>The most significant risk for contaminants is from bare hard surface pads used to hold animals for extended periods of time (that are without effluent capture and management)</td></tr>
<tr><td>Consequences of this can be:
• High volumes of effluent runoff
• High contaminant levels in runoff
• Direct discharge of significant volumes of effluent runoff into waterways either directly or via farm drainage networks
• Degradation of surface water bodies by ammonia, microbial contaminants.
• Enhanced eutrophication of downstream waterbodies</td></tr>
<tr><td>A medium-high risk is permeable bare hard pads that allow high levels of leaching into groundwater</td></tr>
<tr><td rowspan="4">Medium</td><td>Consequences of this can be:
• Discharge of high contaminant loads (E.coli, N) to groundwater
• Degradation of groundwater quality and usage
• Possible degradation of small surface waterways in close proximity</td></tr>
<tr><td>A medium risk is drainage and discharge from sealed pads that contain soft absorbent bedding materials out onto paddock and into the drainage network:</td></tr>
<tr><td>Consequences of this can be:
• High contaminant loads to surface and groundwater after heavy rainfall
• Degradation of water quality (ground and surface water)</td></tr>
<tr><td>A medium to low risk is from management of spent bedding materials and effluent scraping solids.</td></tr>
<tr><td>low</td><td>Consequences of this can be:
• Leaching or runoff from stockpiled material transports contaminants into waterways</td></tr>
</table>

[10] This 'relative' ordering is a subjective assessment of the different pad practices based on possible consequences and their significance.

4 Field Evaluation of Permitted Activity Rule – Guidelines and Key Criteria

4.1 Evaluation Practices – Overview

This section of this report provides guidance notes to assist monitoring and compliance staff in the identification and evaluation of non-compliance with the feed pad and stand-off pad rule and their potential impact on water quality.

These guidelines follow an assessment framework that considers three aspects of evaluation:

1. Current compliance assessment
2. Evaluation of the risks for future compliance
3. Encouraging the adoption of best management practices

The process for this assessment framework is outlined in Figure 13.

The guidance for each Permitted Activity (PA) rule is provided in the form of tables in Section 5.5. The tables identify unacceptable outcomes, risks that could lead to unacceptable outcomes and areas where improvements could be made in practices.

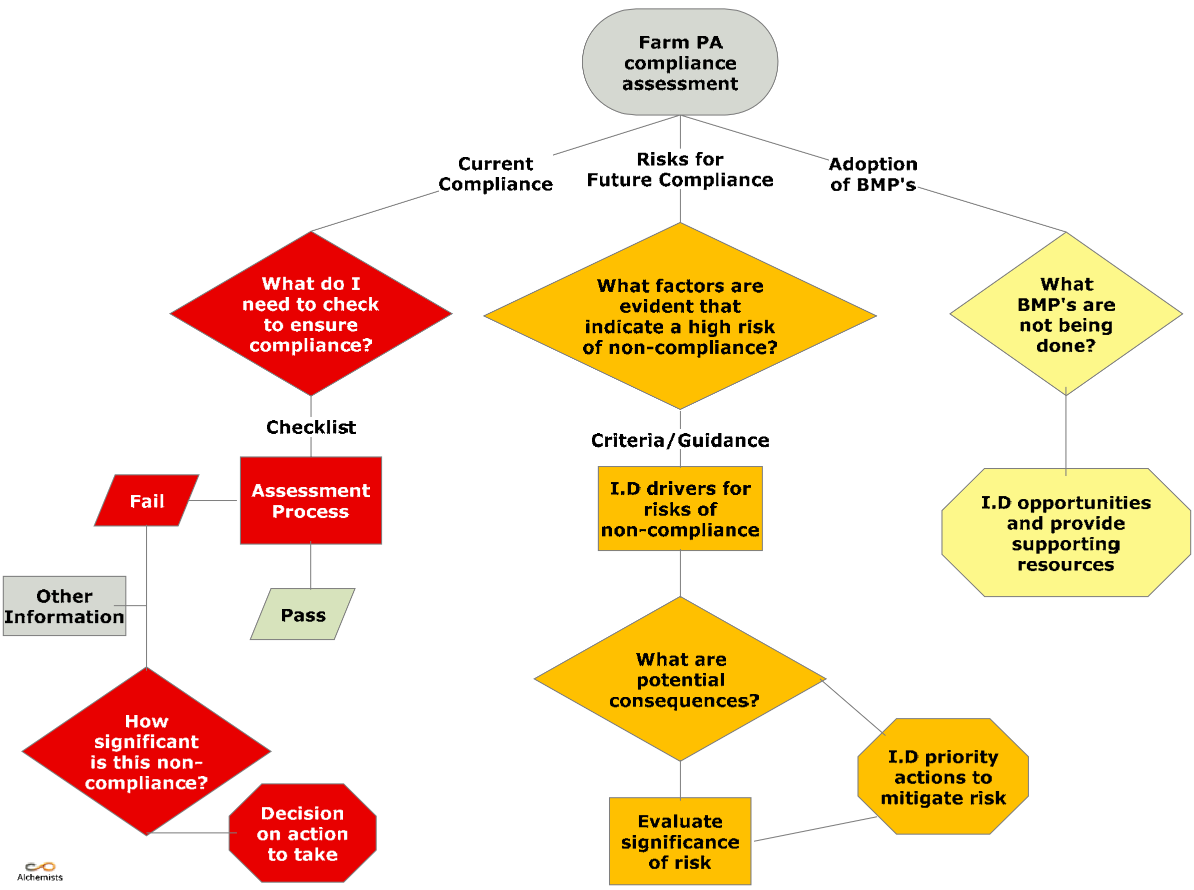

Figure 13: Compliance assessment framework

PA compliance assessment is primarily involved with assessing whether a resource user is complying with the conditions of a PA rule. The process involves assessing current farm practices against the conditions of the rules to determine if they comply. As compliance can only be assessed at that instant in time it is also useful to assess the relative risk that non-compliance might occur at some other time or under changed circumstances.

4.2 Assessment of Compliance

As the assessment process is subjective it is helpful to provide a consistent approach and assessment criteria for existing and new staff to use. The Resource Use Group at Waikato Regional Council has established an existing guideline for assessing compliance status (DOC# 767804). This approach assesses compliance status on individual conditions and then compliance status for an individual consent or entire site (see Appendix 2). It provides definitions for significance of non-compliance and priority levels of non-compliance.

This assessment framework focuses on what are the key compliance criteria to pay attention to when assessing permitted activity rules. These criteria are chosen as they could be strongly indicative of an unacceptable compliance outcome. These criteria are only aiming to identify high and medium priority non-compliances.

4.3 Assessment of Risk

Understanding a risk assessment for contaminant loss from this permitted activity rule can provide staff with an increased understanding of high risk areas that should be the focus on when undertaking monitoring and compliance. It will also highlight areas where uncertainty means more subjective decisions are required

The Table in Section 3.3.7 have identified what the important risks are. This step of the field assessment process is about looking into the probability of any risks and identifying ways to minimise their occurrence and possible significance of any impact should they occur (Figure 14).

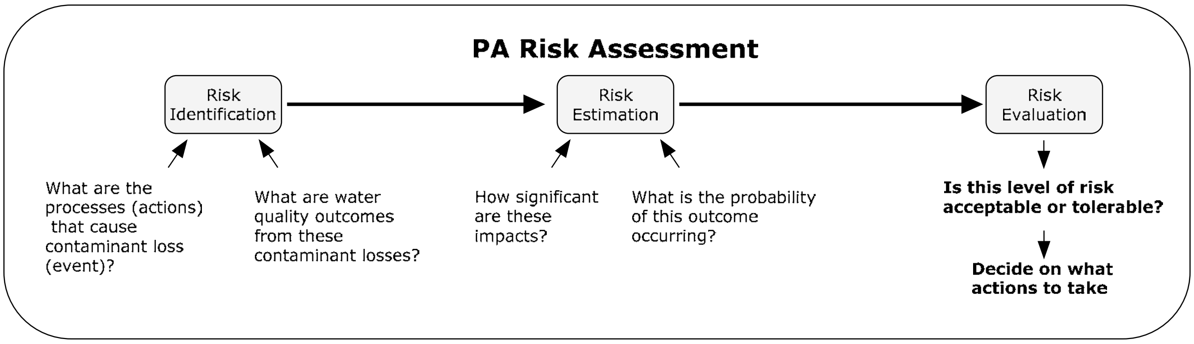

Figure 14: Applying risk assessment process to permitted activity areas

The Tables in Section 4.5 identifies drivers of risk for different pads systems covered by the PA rule, describes potential outcomes that could result, and suggests mitigation options.

4.4 Identifying Opportunities

Although not strictly part of compliance assessment, it is useful for monitoring and compliance staff to understand and identify opportunities for practice improvements. Doing this could help to reduce the future risk for contaminant losses, but also assist farmers to improve their systems. Where possible ideas for improvement opportunities have been identified and linked to available resources.

Efforts to reduce nitrogen concentration in urea from feed manipulation would reduce the overall farm impact but not the percentage of the total farm contribution from the use of feedlots or pads.

4.5 Evaluation of different Feed and Standoff Pad Systems

The evaluation of feed and stand-off pads should utilise the understanding of the potential for pollution and the key drivers of risk as outlined above in Section 3. On the basis that effluent from a stand-off pad with absorbent material produces similar effluent to FDE and therefore has a similar risk and management requirements the evaluation outlined in this report uses FDE as a relative benchmark. Figure 15 provides a summary of the factors that would increase or decrease the relative risk from pad systems and provides direction for the compliance and risk assessment guidelines below.

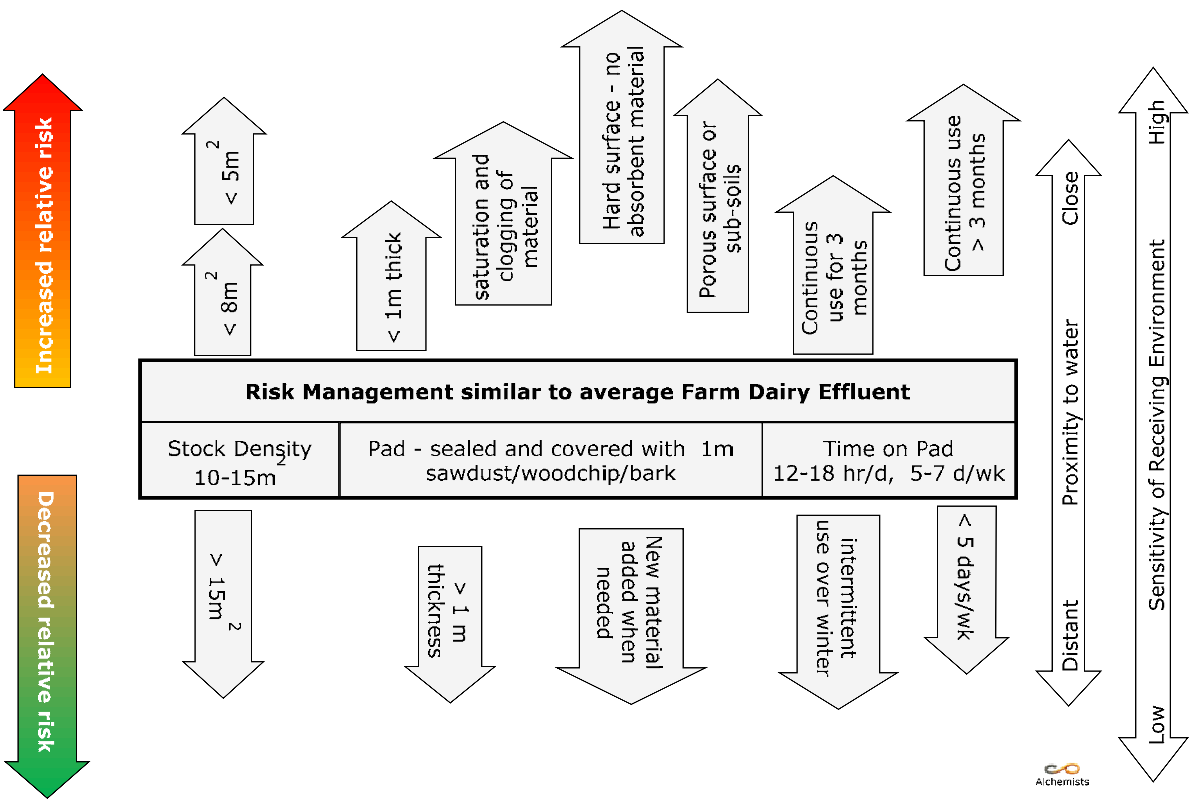

Figure 15: Factors to consider when assessing relative risk of different pads systems

This assessment considers the drivers of three key areas: stocking density; pad structure and surface material; and intensity of use. Other generic factors, such as proximity to water, are identified on the right.

4.5.1 Feed Pads and Standoff Pads – WRP Permitted Activity Rule 3.5.5.2

ASSESSING COMPLIANCE

The details of this permitted activity rule are outlined in Appendix 1. The assessment of compliance for this rule should be undertaken to be consistent with the PA rule for farm dairy effluent (WRP Rule 3.5.5.1 – See Appendix 1). The key criteria for assessing compliance with the feed pad /standoff pad rule are:

- Pad is sealed – permeability of < $1x10^9$ m/s
- No run-off or discharge of pad effluent into surface water
- Solids or effluent when spread on land shall not exceed 150 kg N/ha/yr loading
- Pads should not be located within 20m of surface water or significant geothermal

Further guidance for assessing these criteria is provided.

	Compliance criteria	**Further enquiry**
Presence of unacceptable outcomes	Evidence of runoff or overland flow - Can observe overland flow occurring - See evidence that is has been flowing across paddocks or into waterway	• Has any effort infrastructure or effort been made to capture and manage effluent? • Has discharge or is discharge reaching surface water? • Type and status of receiving waterbody • Estimate volume of effluent flow • How long has it been occurring? – check state of grass under and around flow • Did operator have prior knowledge of issue? • Has any action been taken to stop flow?
	Evidence of ponding in vicinity of pad - Can observe ponding of effluent in depressions near pad - See evidence that ponding has been present	• What is the source – storage facility, directly from pad? • Estimate size of ponding – area and depth • How long has it been occurring? – check state of grass under and around ponding • Soil type and current level of soil moisture • Did operator have prior knowledge of issue? • Has any action been taken to stop flow that is creating ponding? •
	Evidence of leaching/seepage of effluent - There is no hard base on pad	• What are subsoil characteristics • What is the stocking rate on the pad? • How thick is any absorbent material • Does pad have subsurface drainage?

Assessment of compliance for pad systems can be undertaken using a similar checklist process as is used for FDE PA rules. The results can then be used to assess compliance status using the guidelines in Appendix 2.

To focus staff monitoring and compliance effort priority should be to pad systems that are seen to have a higher relative risk that FDE (i.e. fit into the top half of Figure 15). It will be these systems that are having the greatest negative environmental outcomes.

ASSESSING RISK

	Drivers of risk	**Potential outcomes**
Risks that could lead to unacceptable outcomes	No capture or management of effluent	- Direct discharge of effluent to water - Degradation of water quality, stream habitat and water use?
	High stocking rate	- Higher potential for contaminant loss - Overloading of drainage system - Saturation and breakdown of pad cover material -
	Poorly located or excessive slope on pad	- Proximity to stream increases risk of direct discharge to water - Rapid runoff from pad surface -
	Cover material of very dirty and spent	- Loss of treatment potential - Increase concentrations of contaminants in runoff and leaching - Clogging leads to drainage failure and increased runoff of effluent
	Operator knowledge – system, management	- Maintenance not undertaken to minimise risks of runoff and leaching - Solids are not managed corrrectly

PROMOTING GOOD PRACTICE

	Improvement opportunities	**Available Resources**
Areas for attention	Pad preparation	DairyNZ website Dexcel (2005) DEC (2006)
	Pad management – refreshing surface materials	
	Storage/composting of solids	
	Management of adjacent farm runoff	
	Nutrient management	

BMP's (from the 'Dairying and the Environment Manual' (DEC 2006) and 'Stand-off and feed pads: Design and management guidelines' (DEXCEL 2005) unless otherwise stated)

- Using sacrifice paddocks or races is much less favourable than using well-constructed pads. Construction of a stand-off pad should be considered if sacrifice paddocks or races are often used for stand-off.
- Wintering areas should be located well away from surface waterways or bores.
- Sacrifice areas are not best practices and should be seen as a short-term last resort tool. They should be located away from waterways and sensitive areas and any runoff should be managed to avoid direct discharge to waterways.
- The use of Vegetated Filter Strips (VFS) around sacrifice paddocks will reduce contamination by filtering runoff (e.g. Fajardo et al., 2001).
- If races are used for stand-off or feeding they may need extra maintenance. Effluent should be scraped off and collected.
- Effluent management should be planned before the pad is constructed. Calculate effluent volumes based on high use scenarios as trying to make changes later will be more costly.
- Effluent must be collected no matter what surface type is selected. If a soft surface such as woodchip or sawdust is used it must be lined with a concrete, clay or other impermeable product.
- Sub-surface pipe and mole drains are the most common drainage system. However, hump and hollow drainage works well combined with subsurface drains particularly on sites with little or no slope.
- Provide treatment for runoff either by diverting to a pond system and/or using deferred irrigation to land with adequate storage during wet weather.
- Solids separation techniques may be needed to remove extra fibre before irrigation and ponds will need de-sludging at least annually.
- Scraping of sealed surfaces will reduce the volume of water required for cleaning and scrapings can be spread separately on land thereby reducing the solid content of FDE.
- Effluent will have much higher concentrations of N, P and faecal microbes than FDE from the dairy shed so land application areas and oxidation ponds may need to be increased in area/capacity to cope adequately.
- Calculate effluent storage needs using a pond storage calculator. Base calculations on at least a 30 year rainfall dataset
- If wood products are used for the pad surface they can be disposed of separately. To reduce pathogen loadings pad materials should be left to stand for 6 months or composted before application to land to allow time for faecal microbe die-off (Luo et al., 2008). This may impact on other lossess such as ammonia and GHG.
- Feed pads can capture a lot of stormwater. Plan for stormwater loadings and install a mechanism to divert clean stormwater off the area when not in use.
- The volume of drainage could be greatly reduced by the addition of roofs to pads. Roofing of pads may promote higher rates of absorption and immobilisation by carbon rich surface material (Luo et al., 2008).
- It is best to have a separate feeding area outside of the pad; however if feed is supplied within the pad area it should rotated so that 'hot spots' do not develop (Smith et al., 2010).

5 Appendices

5.1 Appendix 1 – Waikato Regional Plan - Permitted Activity Rule

Section 3.5 Discharges

3.5.5.2 Permitted Activity Rule – Discharge of Feed Pad and Stand-Off Pad Effluent onto Land

The discharge of feed pad and stand-off pad effluent to land and the subsequent discharge of contaminants to air is a **permitted activity** subject to the following conditions:

a. The pad shall be sealed, so as to restrict seepage of effluent. The permeability of the sealing layer for such treatment or storage facilities shall not exceed 1x10-9 metres per second.
b. There shall be no run-off or discharge of pad effluent into surface water.
c. Materials used to absorb pad effluent or the effluent itself when spread on land as a means of disposal shall not exceed the limited specified in Table 3-7 inclusive of any loading made under Rules 3.5.5.1, 3.5.5.3, 3.5.6.2, 3.5.6.3 and 3.5.6.4.The pad shall be located at least 20 metres from surface water.
d. Any discharge of contaminants into air arising from this activity shall comply with permitted activity conditions in Section 6.1.8 of this Plan.
e. The discharger shall provide information to show how the requirements of this rule are being met, if requested by the Waikato Regional Council.
f. The discharge shall not occur within 20 metres of a Significant Geothermal Feature*.
g. Where fertiliser is applied onto the same land on which farm animal effluent has been disposed of in the preceding 12 months, the application must be in accordance with Rule 3.9.4.11.

Advisory Notes:

- Discharges of contaminants into or onto land within 20 metres of a Significant Geothermal Feature are addressed by Rules 7.2.6.1 and 7.2.6.2 of this Plan.
- It is considered good practice to locate these pads on firm dry land where there is no risk of run-off into surface water bodies.
- In order to comply with condition b) it is likely that stand-off pads and feed pads will need to be located outside of the floodplain of any water body.
- In relation to sealing feed pads and stand-off pads as referred to in condition a) the permeability requirement of $1x10^{-9}$ metres per second can generally be met through standard compaction procedures on soils with more than 8 percent clay. It the soil has less clay than this, special measures may be required (e.g. an artificial liner). Also, clays may not be suitable for storage facilities that are regularly emptied or are left dry for some time. Environment Waikato can provide advice on soil types and sealing requirements.
- When siting feed pads it is recommended that farmers also check the requirements of the relevant District Plan which may control issues such as buffer distances from neighbouring properties.
- Surface waters under condition d) include all road side drains.

3.5.5.1 Permitted Activity Rule – Discharge of Farm Animal Effluent onto Land

The discharge of contaminants onto land from the application of farm animal effluent, (excluding pig farm effluent), and the subsequent discharge of contaminants into air or water, is a **permitted activity** subject to the following conditions:

a. No discharge of effluent to water shall occur from any effluent holding facilities.
b. Storage facilities and associated facilities shall be installed to ensure compliance with condition a).
c. All effluent treatment or storage facilities (e.g. sumps or ponds) shall be sealed so as to restrict seepage of effluent. The permeability of the sealing layer shall not exceed $1x10^{-9}$ metres per second.
d. The total effluent loading shall not exceed the limited as specified in Table 3-7, including any loading made under Rules 3.5.5.2 and 3.5.5.3, 3.5.6.2, 3.5.6.3 or 3.5.6.4.
e. The maximum loading rate of effluent onto any part of the irrigated land shall not exceed 25 millimetres depth per application.
f. Effluent shall not enter surface water by way of overland flow, or pond on the land surface following the application.
g. Any discharge of contaminants into air arising from this activity shall comply with permitted activity conditions in Section 6.1.8 of this Plan.
h. The discharger shall provide information to show how the requirements of conditions a) to g) are being met, if requested by the Waikato Regional Council.
i. The discharge does not occur within 20 metres of a Significant Geothermal Feature*.
j. Where fertiliser is applied onto the same land on which farm animal effluent has been disposed of in the preceding 12 months, the application must be in accordance with Rule 3.9.4.11.

Advisory Notes:

- Dischargers should note that many territorial authorities have specific rules which set minimum separation distances between treatment or disposal systems, adjoining properties, roadways and houses.
- In relation to sealing effluent treatment or storage facilities as referred to in condition c), the permeability requirement of $1x10^{-9}$ metres per second can generally be met through standard compaction procedures on soils with more than 8 percent clay. If the soil has less clay than this, special measures may be required (e.g. an artificial liner). Also, clays may not be suitable for storage facilities that are regularly emptied or are left dry for some time. Environment Waikato can provide advice on soil types and sealing requirements.
- Effluent treatment and storage facilities should be constructed in accordance with the publication 'Dairying and the Environment – Managing Farm Dairy Effluent' (1996) by the Dairying and the Environment Committee. Copies of this guideline are available from the New Zealand Dairy Research Institute, Private Bag 11029, Palmerston North.
- With regard to the effluent application rate in condition d), the standard of 150 kilograms of nitrogen per hectare per year can be converted into a minimum irrigation area and a maximum depth of effluent that can be applied each year. To do this for farm dairy effluent the following factors must be known or estimated:
    a. The amount of nitrogen excreted by the cow – this can vary greatly (depending upon the composition of pasture, fertiliser use and animal management in the milking shed), but generally averages about 20 grams per cow per day.

b. The volume of nitrogen excreted by the cow – this can vary greatly (depending upon the amount of water used for washing down the yard), but averages a volume of 50 litres per cow per day.
c. The average lactation period – this is the average number of days that the cows are milked per season. It depends upon the potential of an area for dairy farming, and pasture management practices. A typical lactation period for cows in the Waikato Region is about 270 days, and can range from 190 days up to 300 days. It is important that each farmer consider their individual situation when estimating lactation period.

- Using the average values as specified, 150 kilograms of nitrogen per hectare per year equated to both:
  a. a land area requirement of 360 square metres per cow (i.e. about one hectare per 27 cows)
  b. an annual effluent loading rate of 75 millimetres per year.
- Discharges of contaminants into or onto land within 20 metres of a Significant Geothermal Feature are addressed by the Rules 7.2.6.1 and 7.2.6.2 of this Plan.
- To comply with condition f) application rates need to be adjusted for soil and seasonal climatic conditions. Generally, ponding should not occur if the application depth requirements in condition e) are complied with and the instantaneous application rates (per second) are appropriate to these conditions. In practice, implementation of this condition will acknowledge that some minor ponding on the land, for short durations may occur where there are areas of soil compaction.

Table 3-3 Nitrogen Loading Rate Calculations For Grazed Pasture

Total N/cow/year	= =	20 g/cow/day x 270 5.4 kg
Nitrogen loading rate Land area required/cow	= = = =	150 kg N/ha/year 5.4/150 0.036 ha 360 m2
Nitrogen loading rate land area required/ 100 cows	= = =	150 kg N/ha/year 5.4 100/150 3.6 ha

Sources of Data/Assumptions (Dairy Farm Effluent Management, 1995. Environment Waikato)

1. Total N/cow/day = 20 g
2. Nitrogen loading rate = 150 kg N/ha/year.
3. Typical lactation period = 270 days.

For the avoidance of doubt, Rule 3.5.5.2 is deemed to cover the periodic desludging of pond and barrier ditch systems and land application of sludge provided that the effluent application rate is less than 150 kilograms of nitrogen per hectare per year. Sludge can be applied to land at a higher rate than 150 kilograms per hectare of nitrogen but this would then be a discretionary activity subject to Rule 3.5.5.4.

5.2 Appendix 2 – Classification guidelines used to assess compliance status

Based on EW Doc# 767804

Compliance status for individual conditions

Compliance Status	**Description**
Not assessed	• Monitoring of this condition was not undertaken during this monitoring event
High priority non-compliance	• The non-compliance has the potential for, or has resulted in, significant adverse effects on the environment.
Medium priority non-compliance	• There is non compliance with limits or other direct controls on adverse effects; and • The non-compliance has the potential for, or has resulted in, a greater than minor increase in the level of effects authorised.
Low priority non-compliance	• There is non compliance with limits or other direct controls on adverse effects; and • The non-compliance has the potential for, or has resulted in, a less than minor increase in the level of effects authorised; and/or • There has been a significant technical non-compliance such as a failure to collect or supply self monitoring data.
Minor technical non-compliance	• There is non compliance with a condition, or part of a condition, that does not directly control adverse effects; and • The non-compliance was not significant in the management of effects. For example a short delay in supplying data or meeting a deadline for a report
Full compliance	• The condition has been complied with

Compliance status for individual consents and the entire site

Compliance Status	**Description**
Not assessed	• Monitoring has not been undertaken at this site during the current financial year
Significant non-compliance	• There has been a high priority non-compliance; and/or • There have been several medium priority non-compliances.
Partial compliance	• There has been a medium priority non-compliance; and/or • There have been several low priority non-compliances.
High level of compliance	• There has been a low priority non-compliance; and/or • There have been several minor technical non-compliances.
Full compliance	• All conditions that include limits or other direct controls on adverse effects have been complied with. • A small number of minor technical non-compliances may have occurred.

6 References

Burgess, C. (2003). Reporoa Nitrogen Leaching Trial 1998-2002 Final. Environment Waikato Technical Report 2003/15. Hamilton, Environment Waikato**:** 78.

Christensen, C. L., J. Hanly, M. Hedley and D. Horne (2011). Nitrate Leaching and Pasture Production from Two Years of Duration-Controlled Grazing. 24th Annual FLRC Workshop, Massey University, Fertiliser and Lime Research Centre.

Clark , C. E. F., K. L. M. McLeod, C. B. Glassey, P. Gregorini, D. A. Costall, K. Betteridge and G. J. Jago (2010). "Capturing urine while maintaining pasture intake, milk production, and animal welfare of dairy cows in early and late lactation " Journal of Dairy Science **93**: 2280-2286.

CREH (2005). Flow and leachate characteristics of four woodchip corrals in Scotland. Report to the Scottish Executive. Project reference: CRE/001/03. , Centre for Research into Environment and Health (CREH).

Curran-Cournane, F. (2010). Impacts of livestock grazing on soil physical quality and phosphorus and suspended sediment losses in surface runoff Soil Science. Christchurch, Lincoln University. **PhD**.

de Wolde, A. (2006). An alternative wintering system for Southland: A comparison of wintering cows outside, on brassica crops versus inside, in a free stall barn in Southland, New Zealand. Christchurch, Lincoln University. **Master of Professional Studies**

DEC (2006). Chapter 4: Effluent from feed pads, stand-off areas and other sources. Dairying and the Environment Manual, Dairying and the Environment Committee.

DEXCEL (2005). Stand-off and feed pads: Design and management guidelines**:** 44.

Dumont, P. A., D. R. Chadwick, P. French, E. Sagoo and K. A. Smith (2010). Effluent quality from out-wintering pads. Ramiran 2010: Treatment and use of organic residues in agriculture, challanges and opportunities towards sustainable management. Lisboa, Portugal, Ramiran.

EPA (2007). Environmental regulation using a risk-based approach, Environmental Protection Agency - South Australia.

Fajardo, J. J., J. W. Bauder and S. D. Cash (2001). "Managing nitrate and bacteria in runoff from livestock confinement areas with vegetative filter strips." Journal of Soil and Water Conservation **56**(3): 185.

Haynes, R. J. and P. H. Williams (1993). Nutrient Cycling and Soil Fertility in the Grazed Pasture Ecosystem. Advances in Agronomy. L. S. Donald, Academic Press. **Volume 49:** 119-199.

Houlbrooke, D. J., D. J. Horne, M. J. Hedley, J. A. Hanly and V. O. Snow (2004). "A review of literature on the land treatment of farm-dairy effluent in New Zealand and its impact on water quality." New Zealand Journal of Agricultural Research **47**(4): 499-511.

Houlbrooke, D. J., R. M. Monaghan and M. Mcleod (2010). Matching farm dairy effluent storage requirements and management practices to soil and landscape features, AgResearch**:** 43.

Judge, A. and S. Ledgard (2004). Nutrient budgets for Waikato dairy and sheep/beef farms for 1997/98 and 2002/2003. Environment Waikato Technical Report 2004/19. Hamilton, Environment Waikato**:** 32.

Ledgard, S., M. Sprosen, A. Judge, S. Lindsey, R. Jensen, D. Clark, J. luo and (2006). Nitrogen leaching as affected by dairy intensification and mitigation practices in the Resource Efficient Dairying (RED) trial. . Implementing sustainable nutrient management strategies in agriculture (Eds. L.D. Currie & J.A. Hanly),. Palmerston North, New Zealand., Fertilizer and Lime Research Centre, Massey University**:** pp. 263-268.

Longhurst, R. D., A. H. C. Roberts and M. B. O'Connor (2000). "Farm dairy effluent: A review of published data on chemical and physical characteristics in New Zealand." New Zealand Journal of Agricultural Research **43**: 7-14.

Luo, J., A. Donnison, C. Ross, N. Bolan, S. Ledgard, D. Clark and W. Qiu (2008). "Sawdust and bark to treat nitrogen and faecal bacteria in winter stand-off pads on a dairy farm." New Zealand Journal of Agricultural Research **51**(3): 331-340.

Luo, J., C. Donnison, S. Ross, S. Ledgard and B. Longhurst (2006). "Control of pollutants using stand-off pads containing different natural materials." Proceedings of the New Zealand Grassland Association **68**: 315-320.

McDowell, R. W., J. J. Drewry, R. W. Muirhead and R. J. Paton (2005). "Restricting the grazing time of cattle to decrease phosphorus, sediment and E. coli losses in overland flow from cropland." Australian Journal of Soil Research **43**: 61-66.

McDowell, R. W., S. Larned and J. Phillips (2008). A Commentary on Agricultural Sources, Transport and Impact of Phosphorus in Surface Waters: Knowledge Gaps and Frequently Asked Questions Report prepared for Unitary Authorities via Envirolink, AgResearch.

Menneer, J., S. Ledgard and A. Gillingham (2004). Land use impacts on nitrogen and phosphorus loss and management options for intervention Client Report prepared for Environment Bay of Plenty. Hamilton, AgResearch.

Miller, J. J., B. P. Handerek, B. W. Beasley, E. C. S. Olson, L. J. Yanke, F. J. Larney, T. A. McAllister, B. M. Olson, L. B. Selinger, D. S. Chanasyk and P. Hasselback (2004). "Quantity and Quality of Runoff from a Beef Cattle Feedlot in Southern Alberta." Journal of Environmental Quality **33**: 1088-1097.

Monaghan, R. M. (2008). The environmental impacts of non-irrigated, pasture based dairy farming. The environmental impacts of pasture based farming. R. W. McDowell. Oxfordshire, CAB International**:** 209-231.

Monaghan, R. M., C. A. M. de Klein and R. W. Muirhead (2008). "Prioritisation of farm scale remediation efforts for reducing losses of nutrients and faecal indicator organisms to waterways: A case study of New Zealand dairy farming." Journal of Environmental Management **87**: 609-622.

Monaghan, R. M., C. A. M. De Klein, D. Smeaton, D. Stevens, M. G. Hyslop, J. J. Drewry, L. C. Smith and B. S. Thorrold (2004). The environmental and economical performance of dairy systems within the four Best Practice Dairy Catchments. Client report prepared for FertResearch. Hamilton, AgResearch.

Monaghan, R. M., M. Hedley, H. J. Di, R. W. McDowell, K. C. Cameron and S. Ledgard (2007). "Nutrient management in New Zealand pastures - recent developments and future issues." New Zealand Journal of Agricultural Research **50**: 181-201.

Monaghan, R. M. and B. Longhurst (2007). Appendix VI Evaluation of dairy wintering systems on the West Coast. Linkages between land management practices and potential impacts on soil and water quality within the Inchbonnie catchment R. M. Monaghan, A. Rutherford, R. W. McDowell and C. M. Smith. Hamilton, AgResearch.

Monaghan, R. M. and L. C. Smith (2004). "Minimising surface water pollution resulting from farm-dairy effluent application to mole-pipe drained soils. II. The contribution of preferential flow of effluent to whole-farm pollutant losses in subsurface drainage from a West Otago dairy farm." New Zealand Journal of Agricultural Research **47**(4): 417-428.

Monaghan, R. M., R. J. Wilcock, L. C. Smith, B. Tikkisetty, B. S. Thorrold and D. Costall (2007). "Linkages between land management activities and water quality in an intensively farmed catchment in southern New Zealand." Agriculture, Ecosystems and Environment **118**: 211-222.

Morris, B. (2010). "Groundwater and Pathogens." 2011, from http://www.groundwateruk.org/downloads/Pathogens_and_groundwater_final%20version.pdf.

Power, I., S. Ledgard and R. M. Monaghan (2002). Nutrient Budgets for Three Mixed Farming Catchments in New Zealand. MAF Technical Paper**:** 37.

Pyle, E. and J. Gough, D. (1991). Environmental Risk assessment for New Zealand Centre for Resource Management.

Selvarajah, N. (1999). Dairy fram effluent pond treatment performance in the Waikato Region: A preliminary survey. Tertiary treatment options for dairyshed and piggery wastewaters, Massey University.

Singh, A., J. R. Bicudo and S. R. Workman (2008). "Run and drainage water quality from geotextile and gravel pads used in livestock feeding and loafing areas." Bioresource Technology **99**: 3224–3232.

Singleton, P. L., M. Boyes and B. Addison (2000). "Effect of treading by dairy cattle on topsoil physical conditions for six contrasting soil types in Waikato and Northland, New Zealand, with implications for monitoring." New Zealand Journal of Agricultural Research **43**(4): 559-567.

Smith, C. and R. M. Monaghan (2009). Contaminant runoff from dairy farm laneways in the Bog Burn catchment - Year 1 Results, AgResearch**:** 10.

Smith, K. A., D. R. Chadwick, P. A. Dumont, J. P. Grylls and S. Sagoo (2010). Woodchip pads for out-wintering cattle - technical review of environmental aspects. Report delivered under the project “Improved design and management of woodchip pads for sustainable out-wintering of livestock” under the DEFRA Sustainable Livestock LINK Research Programme (Project LK0676).

Sonthi, R. K. (2010). Gaseous emissions (NH_3, N_20 and CH_4) following manure or urea application to soil as influenced by amendments. Earth Sciences. Hamilton, University of Waikato. **MPhil**.

Sweeton, J. M. (1988). Cattle feedlot manure and waste management practices. Animal waste utilisation: Effective use of manure as a soil resource. J. L. Hatfield and B. A. Stewart. Chelsea, MI, Ann Arbor Press.

Vinten, A. J. A., S. Donnelly, B. C. Ball, C. E. Crawford, R. M. Ritchie and J. P. Parker (2006). "A field trial to evaluate the pollution potential to ground and surface waters from woodchip corrals for overwintering livestock outdoors." Soil Use and Management **22**(1): 82-94.

Wilcock, R. J. (2006). Assessing the relative importance of faecal pollution sources in rural catchments. Environment Waikato Technical Report 2006/41. Hamilton, Environment Waikato**:** 30.