PART 5

Feed Pads

1.0 Introduction

A feed pad provides a facility for the supplementary feeding of cows. Farmers who use a feed pad aim to maintain or increase quality or quantity of milk and avoid deterioration of tracks or pastures. Critical aspects in the design and construction of a feed pad operation are:

- Safe and easy access for stock
- Maintenance of animal health
- Adequate working space for farm staff and their equipment
- Storage of a range of feeds and easy access to them
- Efficient feeding out system
- Water supply
- Farm Dairy Effluent (FDE) containment
- Stormwater management
- Shelter

The size and arrangement of the pad depends on the operation. The pad operation needs to be efficient, sustainable, and appropriate for herd size, as well as meeting regional council rules and regulations.

Tables 5.3 and 5.4 have been developed to provide general guidance on slab thickness and concrete strength selection depending on the intended feed pad durability and loading conditions.

1.1 Scope

This Practice Note part is limited to feed pads constructed with concrete pad surfacing and without a roof or covering structure. Part 4: Concrete Structures is directly relevant and should be read in conjunction with this part.

KEY POINTS

- Regional council requirements for feed pads vary within New Zealand
- Concrete feed pads provide one of several off pasture feeding options
- The feed pad site should only be confirmed after thorough site investigations have been completed
- The required feed pad area needs to take account of the proposed maximum stock numbers, feeding regime, access and vehicle turning movements
- Because of the acidic and corrosive environment created by stock on feed pad surfaces, these require a concrete designed for high durability to provide a long service life
- Concrete slab design needs to be reviewed by a professional engineer
- Proper site preparation, placement and curing of concrete is critical to achieve the intended design performance
- The proposed effluent management system needs to be designed into the structure, not added in later
- An upgrade of the farm FDE system (including deferred storage) may be necessary to accommodate the additional FDE generated
- Constructing and maintaining a surface that is not rough or slippery is critical for animal welfare.

2.0 Decision Making

2.1 Off Pasture Options

Feed pads are different to other off pasture feeding options. A feed pad is a defined hard surface area, typically concrete, sited adjacent to the farm dairy where stock can be held for a short period of time (up to two hours) either before or after milking, where water and supplementary feed can be provided. They are not designed for holding cows for extended periods of time. They may be covered, or uncovered.

As well as water, feed pads can be used to feed hay, silage, mixed rations or concentrates in times of pasture shortage. They can reduce the adverse impact of stock on pasture during wet conditions or pasture renovation. Concrete feed pads provide better supplement utilisation than supplement feeding on pasture.

On feed pads, the FDE flows down the concrete surface to the edge of the slab where it is channelled to a sump for collection and subsequent storage or irrigation disposal. Non-concrete hard surfaces such as gravel are not recommended for feed pads due to the combined challenges of keeping the surface clean, containing effluent and maintaining animal health.

Depending on the operation of the farm, other types of off pasture pad systems should also be considered. These are listed in table 2.1. The general principles described in this Part apply to all types of feed pad, although the specific design features associated with covered pads are not included.

Stand-off (or Loafing) Pad: Specially built uncovered areas where stock can be withheld from grazing during wet periods to minimise damage to pastures. Pads are constructed of free-draining material such as sand, bark, saw dust or woodchips on a sealed surface with appropriate drainage of liquid to an effluent storage facility. Because cows may be withheld for extended periods they need 8 to 10 square metres per cow to allow room for lying down.

Self-feed Pad: Constructed where animals are withheld from pasture for extended periods and supplementary feed is given to them on an uncovered pad, for example over winter. As the herd may spend several months on the pad, the cows require a similar sized area as a stand-off pad to lie down on, in addition to a hard area for feeding.

Animal Shelter: These are covered facilities for when animals are held off pasture, usually for shorter term periods, and supplementary feeds are brought to them. Pad surfaces can be either concrete slatted floor with manure storage bunker or free-draining carbon material. They don’t include designated areas for cows to lie down.

Wintering Barn: These are fully covered and enclosed facilities where animals are withheld from pasture for extended periods and supplementary feeds brought to them. They are commonly constructed with a concrete floor and have designated areas for cows to lie down on which have a softer surface (for example, rubber matting).

Table 2.1: Other Types of Off-Pasture Pad Systems


Uncovered feed pad


Covered feed pad


Stand-off (or loafing pad)


Self-feed pad


Animal shelter


Wintering barn

2.1.1 SURFACING

The critical consideration when choosing the type of pad system is usually the intended length of time cows will spend on its surface. The surfacing type chosen should be determined by a balance of factors including:

- The ability to feed out efficiently
- Longevity of the surface
- Ability to clean the surface and capture effluent
- Animal wellbeing.

The longer a cow spends on a hard or wet surface without being able to lie down, the greater the risk of stress and lameness.

If the pad is used for feeding only, then the cows should only be there for a few hours each day and in this situation a surface such as concrete is acceptable. However, if it is intended to use the pad for prolonged periods, such as for winter management, then a softer surface for animals to lie down on will be needed.

2.2 Feed Pad Considerations

While there are considerable benefits to be gained from installing a feed pad, the bigger picture needs to be considered before making a decision to proceed. The following farm management related questions in Table 2.2 should be carefully considered by the farmer in consultation with their advisors.

- How will pasture management be adjusted to maximise efficiency?
- How will a pad impact the farm’s profitability?
- What will the pad be used for?
- How will animal health and welfare on the pad be managed?
- How will the proposed system be operated long term, for example feed management?
- Will a change in system align with goals for the farm?
- Will the farm change to a higher input feeding system?
- Does the farm have sufficient staff to run a supplementary feed system?
- How will the increased effluent and stormwater generated from the pad be managed?

Table 2.2: Feed pad Considerations

An integrated farm planning approach is essential in deciding the site, size and viability of a pad. To be effective, a feed pad needs to be considered as one component in a whole farm system. It must take into account proposed future changes in the farming systems and herd size. At the outset a cost versus benefit analysis should be undertaken to confirm viability.

Feed pad in operation

3.0 Regulatory

3.1 Regional and District Council Rules

Different local authorities have different rules for feed pads, particularly around the means by which FDE is managed. However, they usually include rules about the construction materials and sealing requirements of the pad as well as proximity to boundaries, public roads, water bores and neighbouring houses. Therefore, the relevant regional and district councils must be consulted before construction to identify any rules or regulations that may apply for the proposed feed pad site. The role of councils under the Resource Management Act (RMA) is included in Part 1: Legislation section 3 of this Practice Note.

In some regions, the construction and/or operation of a new feed pad may be a non-compliant activity under existing land use and discharge consents, thereby invoking the need for a consent variation.

3.2 Ministry for Primary Industries

NZCP1: Code of Practice for the Design and Operation of Farm Dairies has been developed by the Ministry of Primary Industries (MPI) to assist the dairy industry in meeting certain aspects of the Animal Products Act 1999. This code of practice covers minimum distances between the milk contact areas and sources of food contamination. Factors such as feed storage, effluent containment and rodent control also need to be considered. Parts of NZCP1 relevant to feed pads have been reproduced in Part 1: Legislation, section 6.

MPI also administers *The Animal Welfare (Dairy Cattle) Code of Welfare*. It contains minimum standards for farm facilities and feed pads and has been reproduced in part in section 7 of Part 1: Legislation.

4.0 General Design

4.1 Site Selection

Feed pads should be formed above the natural ground surface level to promote drainage. The design should allow for all-weather access by machinery and cows, as well as for waste removal. Positioning needs to be dictated by the location of the milking shed's access track and the holding yard and should be sited as multipurpose facilities which can be used to benefit the farm all year round. Some site considerations are listed below.

- Sufficient space for vehicles to access and easily turn
- Existing site services available (water, power, FDE storage and treatment, fresh water)
- Take advantage of any gentle slope (2 to 4 percent)
- Make use of existing shelter belts
- Consider prevailing winds
- Proximity and accessibility to dairy shed and feed bunkers
- Room for future expansion
- Topography
- Ground water level
- Drainage features
- Clearance distance from property boundaries
- Minimum allowable distance from waterways and bores
- Ease of cow flow.

Table 4.1: Some Practical Site Considerations for Feed pads

4.2 Site Investigations

4.2.1 SURVEY

A topographic survey of the whole site will assist in optimising the feed pad location. Surface features such as buildings, trees, water courses, power and telecom lines, roads, races, and fences should be located and presented on a site plan. The location of buried services such as electricity and telecom cables, and water and gas lines also must be recorded on the site plan - before test pits are dug. The proposed pad "footprint" can then be overlain on the plan to determine its optimal positioning with respect to surrounding features and services.

The feed pad position should also be optimised to reduce the quantity of earthworks required. A pad surface requires sufficient slope to assist liquid drainage by gravity. A minimum surface slope of 2 percent is usual and is equivalent to a fall of 20 millimetres over 1 metre.

4.2.2 TEST PITS

Test pits across the site to at least one metre below the finished depth of the concrete slab are essential to determine the type and characteristics of the sub soil materials present under the proposed pad. Locating the highest seasonal ground water level is critical as it will assist in determining the level of the base of the pad and its foundations.

Before digging a test pit, ensure no buried services are located under the proposed site of the pit.

Scala penetrometer tests to determine soil bearing pressures are recommended to calculate the depth of compacted gravel that should be placed on the prepared ground to provide foundation support, especially if it is intended to enclose the pad or cover it with a roof in the future.

4.3 Dimensions

Feed pad dimensions will always need to be farm specific but general guidelines are:

- Allow feed lanes 4.5 to 6.0 metres wide for easy tractor and feed-out wagon access as well as sufficient cow standing area
- Single lanes for cows only should be 4.0 metres wide to allow cows to pass freely
- Length of the feed face for short-time feeding if all cows are able to feed at once should be 0.8 metres per cow
- Length of the feed face if cows are feeding adlib should be 0.3 to 0.5 metres per cow
- Entry and exit points, as well as turning areas for cleaning and feeding out, should be wide enough (at least 8 to 10 metres) to allow free flow of stock and vehicles.

The area allowed per cow will affect their comfort levels. Cows standing in a yard before milking occupy between 1.2 square metres (Jersey) and 1.5 square metres (large Friesian) each, depending on breed. Where cows will be on the feed pad for short periods an area of at least 3.5 square metres should be allowed for.

Any intended herd size increases, or changes in breed, need to be allowed for by providing flexibility to change the overall pad dimensions and configuration at a future time.

4.4 Orientation

The orientation of a pad should be carefully considered. Relevant factors are:

- Can shade be maximised by positioning close to tree lines?
- Can the negative effects of prevailing winds be minimised?
- Is it intended to cover the pad with a roof structure or enclose it entirely at some future time? (This is very relevant on a sloping site). If so:
  - What type of roof structure would be constructed?
  - How would roof water be collected and disposed of?
  - How would the roof be supported from the ground?

4.5 Surface Slope

The recommended surface slope for feed pads is 2 percent to address the following needs:

- Cow behaviour is improved where the surface slope is not greater than 2%.
- (Cows at greater grades become uncomfortable standing across a slope and will naturally turn up-hill)
- Ease of cleaning, and drainage of FDE
- Drainage of surface stormwater, which can effectively gravity flow downslope
- Research suggests a 2 percent slope is optimal for flood wash.

  (At steeper slopes wash down becomes inefficient as rivulets will form leaving solids behind.)

4.6 Covering

For economic reasons farmers may consider constructing a feed pad in the short term but add a roof structure to provide shade and shelter for cows later. A roof can divert rainfall directly to stormwater so there is less FDE volume on the pad to manage.

Foundation requirements for a roof or covering structure that may be added later should be considered during the concrete slab design stage as it will be subject to building consent and the *New Zealand Building Code (NZBC)* requirements.

Design of post foundation at this stage may make any future addition covering less difficult and more cost effective. A cost versus benefit analysis should be undertaken first as retrofitting a roof may not be as cost effective as first envisaged for some sites. However, short term financial benefits of not allowing for addition of a future roof structure may be overtaken by changes in future costs and overall economics of the farm operation. Therefore reducing up-front cost should not be the only basis for the decision.

Guidance around the design and construction of structures suitable for covering feed pads is outside the scope of this Practice Note.

Covered feed pad

4.7 Drainage

Good design around the drainage system is critical for both animal health and effluent management on the feed pad. All feed pad liquid, that is both FDE and stormwater, must be captured.

Key points around effective feed pad drainage are:

- Minimising the amount of water flowing into the pad area by using cut off drains with subsoils encased in filter gravel to collect both ground and surface water. Areas prone to flooding or frequent high ground water levels should be avoided.
- Where surface water flow onto the pad from beyond its perimeter could be an issue, a cut off drain or stormwater channel around the exterior of the pad should be installed (for example around the outside of a perimeter nib wall).
- At times when the pad is not being used, the stormwater runoff should be able to be diverted to land through surface water channelling. This reduces the volume that would otherwise be entering the FDE system.

- Any stormwater contaminated with effluent needs to be collected and treated through the FDE system. If the pad has uncovered feed stored on it, such as silage, leachate may flow out and so this area must similarly discharge to the FDE system.

This Practice Note assumes for design and operation that feed pad slabs will be constructed wholly above maximum ground water levels.

4.8 Access

Lameness can be a major problem in some herds. One cause is small, hard stones catching in cows' hooves when they step from the race onto a concreted area. Options for avoiding this include:

- Applying a compacted layer of softer rock as a capping material to the surface of the entrance race
- Installing a specifically developed proprietary geotextile fabric on the approach
- Constructing a nib wall barrier at the feed pad access entrance.

The entrance to the feed pad is a collection point for effluent and needs to be sloped, well drained and diverted into the effluent treatment system.

4.9 Water Supply

An adequate water supply at the pad for stock is essential. Volumes required can be calculated by considering:

- Lactating cows require between 70 and 110 litres of water per day
- Dry cows require between 35 to 80 litres of water per day
- When cows are fed more concentrated supplements with higher dry matter (DM) their water intake will increase above 70 litres
- Adequate water must be available for cleaning purposes.

Water troughs should be placed well away from feed troughs and bins to reduce cross contamination by stock and ensure that dominant cows can't monopolise both the feed and water at the same time. Allowing a sufficient feed and drinking face width based on what works well on similar feed pads will also assist.

4.10 Feeding Facilities

Supplementary feeds can be provided by a number of different feed distribution systems, including:

- Feed bins
- Feed troughs
- Feed lanes

Farmers will usually have their own preferences as to the option they choose.

One of the more difficult aspects of a feed pad operation is ensuring cows are kept out of the feed. A few ideas to consider when designing a feed pad that will help mitigate this are:

- To make feed easily accessible, ensure that the inside floor of the bin, trough or feed lane is at least 200 millimetres higher than the feed pad. The ideal height will vary with the breed.
- Place a hot wire down the centre of the bin or trough. However, consider how the power will safely cross (preferably underground) to the feeding area.
- A costlier but effective option is to install pipe head bails. These not only prevent cows from climbing into or being pushed into bins, they also prevent them from lifting their heads out of the bins and throwing feed around.

Concrete feed bins built into the slab have the advantage that they do not move when they are knocked during feed replenishment and consideration should be given to this in the design of the concrete slab. If feed bins that abut each other are able to move out of alignment then feed can spill onto the ground. However, separate feed bins have the advantage of being easier to replace when damaged or when the configuration of the feed pad is changed for operational purposes.

The designer also needs to consider how bins, troughs and lanes can be cleaned out efficiently.

4.11 Feed Storage

Well placed supplementary feed storage areas can save costs through reduced spoilage, fuel use and travelling time. They also improve operational efficiency by optimising the distance between storage and feeding locations for convenience and safety, and reduce the length of road or track needed for transporting feed in.

Storage facilities that are integrated into the design of a feed pad itself will assist in reducing the impacts of spoilage from rain and surface water, and capture leachate runoff which can be toxic to aquatic life.

All stored feed is best contained in a covered bunker. Feed should be kept dry, protected and a minimum distance away from the milking area. MPI's code of practice *NZCP1* provides further guidance, and includes a section on stock feed storage reproduced in Table 4.2 below.

Stock Feed Storage
Feeds containing grain, palm kernel extract, and similar products should be stored in a feed silo. The silo should be situated on concrete no closer than 10 metres from the vat stand.
Feed that cannot be stored in a feed silo should be stored over concrete or, if a concrete area is not available, then on a sheet impervious to moisture such as polyethylene. Storage must be at least 20 metres from the farm dairy and not within 3 metres of the edge of the farm roadway, and should not allow any water runoff to contaminate the feed pile, surface water or ground water source. In addition:
Feed should not be stored directly on the ground
Feeds containing grain, palm kernel extract, and similar products should be covered at all times to prevent water damage
The feed must be protected from birds, rodents, insects and other vermin
The feed storage area should not be made of any materials that are likely to contaminate the stored feed with residues, such as tanalised timber
Feed should not be stored on-farm for long periods
Mouldy or spoiled feed should never be fed to lactating dairy cows.

Table 4.2: Extract from Chapter 7.9 Stock Feed Storage, NZCP1: Code of Practice for the Design and Operation of Farm Dairies

4.11.1 STORAGE BUNKERS

The walls and floor of reinforced concrete bunkers for feed storage must be capable of withstanding the hard knocks of tractors and other machinery, as well as having sufficient durability and depth of concrete cover over the steel reinforcement to resist corrosion from the very acidic leachate. See Part 4 for general information on concrete durability.

The bunker floor must also be watertight and extend out as a concrete apron in front of the bunker walls. A sloped floor with a nib wall and channel on the down slope side will keep any leachate in, and freshwater out. The leachate is then able to be channelled into the FDE system. Types of concrete structures that could be used to build feed storage are described in Part 4: Concrete Structures, section 6.0 and the general design of solids bunkers detailed in Part 2: Solids Separation, section 5.2.

4.11.2 FEED STACKS

Stacks of feed (for example silage) should be placed on a drained concrete surface constructed with nib walls around the perimeter. Silage covers should extend over the feed and beyond the nib wall and be attached or weighted down on the ground. Rain water is then able to flow down off the cover and flow beyond the pad while the leachate is contained on the concrete.

As a feed stack pad surface is exposed to similar impact, scraping and acid leaching damage as a feed pad, the concrete slab should be similarly designed.

A concept design for a feed stock pad is illustrated in Figure 4.1 below.

Feed stack pad

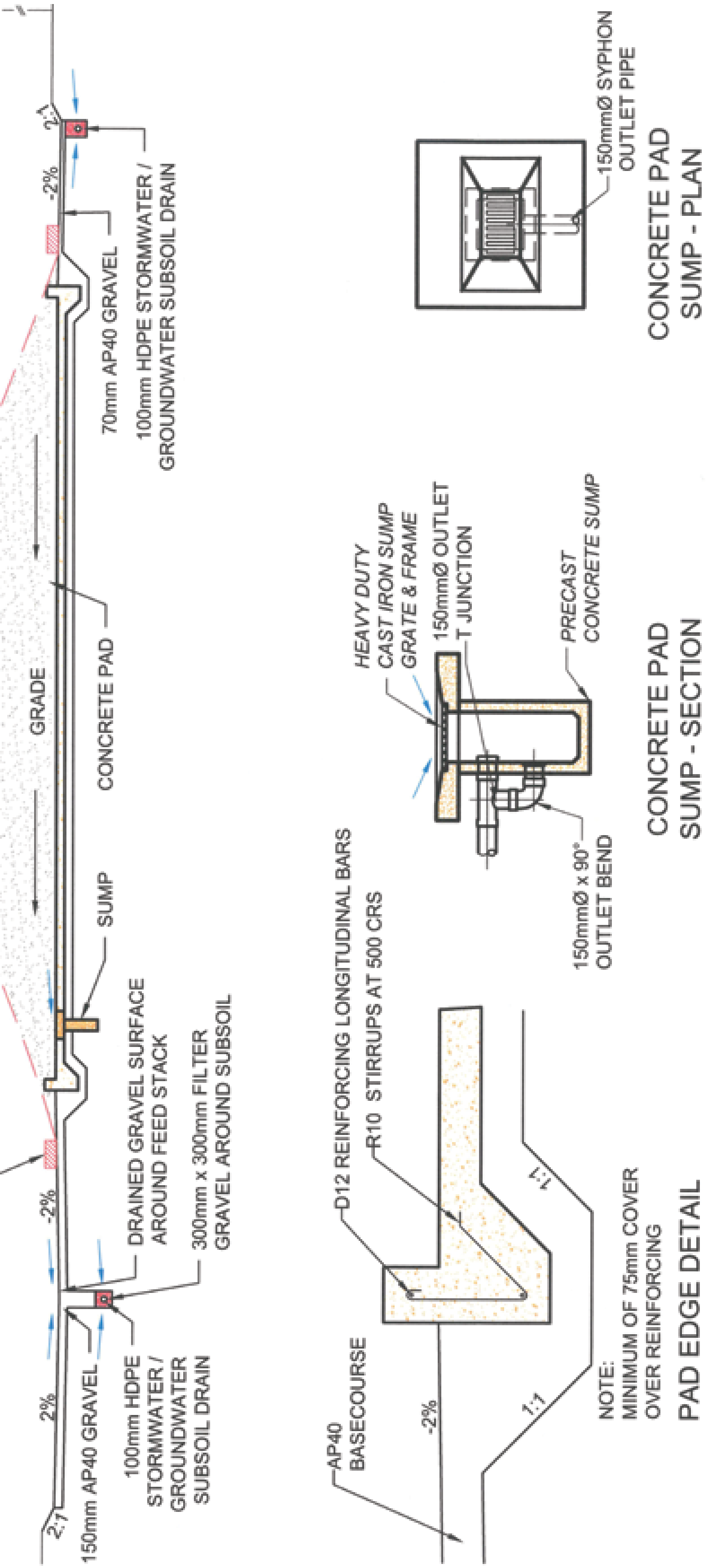

Figure 4.1: Feed Stack - Concept Details

5.0 Slab Design

5.1 Slab Design Considerations

Prior to the design of any concrete slab structure the proposed feed pad site must be fully assessed. Its design should include the following key considerations.

Ground conditions under the slab, including soil type, moisture and plasticity
Maximum ground water level
Levels and grades along the site so to provide effective gravity drainage into the FDE system
Size and shape of the slab
Proposed design life of the slab
Slab surface and serviceability expectations
Intended operation of the feed pad, including means of stocking with feed, vehicle turning areas, cleaning and maintenance
Likely exposure conditions (moisture, soil and groundwater chemistry, acids from FDE and feed leachate, abrasion, freeze-thaw cycles)
Available budget

Table 5.1: Concrete Slab Design Considerations

Many factors will influence the design and construction of a concrete feed pad slab but their individual impacts will vary from site to site. The desired level of durability of the slab should be reflected not only in the design adopted but also in the budgeted amount set aside for the work. A lower construction cost may inevitably require making considered design and performance compromises.

Part 4: Concrete Structures gives general guidance for reinforced concrete design and construction and should be read in conjunction with this Part. Aspects specific to concrete feed pads are outlined in the following sections.

5.2 Design Life

Farm owners should be asked, how long do they need this feed pad structure to last, that is, what is the design, working or intended life.

If it is a temporary structure, it may be more economical to overlook durability requirements. However, in cases where a large economic investment is being made it should be designed for durability. For covered structures, the NZBC and NZS 3604 (Timber-Framed Buildings) require concrete slabs to perform as designed for at least 50 years without needing reconstruction or major renovation.

Part 4 section 4.1.1 of this practice note describes typical “life” for structures covered by the NZ Building Act.

5.3 Exposure and Load Conditions

Depending on the site and operation, feed pads are subject to different environmental exposure and load conditions, including those listed in Table 5.2. Design life and serviceability expectations, will also have a significant impact on the slab.

- Acidic materials (eg FDE, leachate from feed, and some cleaning materials) in wet conditions
- High abrasion from dairy cattle, FDE scraping and manoeuvring vehicles
- Thermal movement from temperature variations
- Impact loading from machinery such as loader buckets
- Exposure to seawater or seaspray.

Table 5.2: Slab Design - Exposure and Load Conditions

Concrete exposed to acidic materials such as those present in FDE or feed leachate will soften, and be easily abraded or eroded. Therefore the thickness of such slabs will be governed not only by the structural load requirements, but also by the depth of cover concrete required to protect the reinforcement from being exposed and corroded.

5.4 Concrete Design - Durability

Concrete can be designed to operate for a prescribed design life with minimal maintenance in a wide range of conditions. Part 4 gives further information on concrete durability, and should be read in conjunction with this part.

In general, the stronger and less permeable the concrete surface and cover concrete, the more durable the element will be.

Abrasion resistance is critical for feed pads. Table 5.3 below provides guidance for minimum compressive strength for feed pad abrasion resistance. 30 MPa is the minimum recommended concrete compressive strength for permanent structures to satisfy structural requirements (see table 5.4). However for feed pads subject to high abrasion, 40 MPa may be appropriate to provide adequate durability.

<table>
<tr><th>SERVICE CONDITIONS</th><th>APPLICATION</th><th>FINISHING PROCESS</th><th>CURING</th><th>MIN SPECIFIED COMPRESSIVE STRENGTH f'_c (MPa)</th></tr>
<tr><td>High abrasion</td><td>Cow standing areas subject to feed out and scraping vehicle movements, (for example feed pads)</td><td rowspan="2">Power floating and at least two passes with a power trowel before applying a slip resistant surface texture</td><td rowspan="2">7 days water curing using ponding or covering; or the use of curing membrane that meets NZS 3109</td><td>40 MPa</td></tr>
<tr><td>Moderate abrasion</td><td>Cow standing areas with light vehicular traffic only, (for example dairy yards)</td><td>30 MPa</td></tr>
</table>

Table 5.3: Selection Guide for Concrete Slab Floors

Durability is further influenced by the depth of concrete cover over the reinforcement and by cracks and joints. Feed pads in environments subject to frost needs to be constructed from concrete that's resistant to freeze-thaw attack.

Proper curing is essential to ensure the required durability and strength is achieved. It is particularly important for durability, which is largely determined by the quality of the concrete surface and cover concrete. Therefore it should not be reduced in the construction process in an attempt to save time or money.

Higher strength concrete and concretes containing a supplementary cementitious material (SCM) are susceptible to cracking within hours of placement under weather conditions that promote rapid drying of the concrete surface. Special precautions must be taken in such conditions to prevent cracks caused by evaporation from the slab during the finishing process.

More information on concrete specification and construction including ordering and storing materials, mixing concrete, placing, finishing, curing, and cutting joints to control cracking is outlined in Part 4: Concrete Structures and *IB 55*.

5.5 Concrete Design - Loading

Table 5.4 provides recommendations applicable to concrete feed pad slabs for given load conditions and should be read in conjunction with other design guidance provided in this Practice Note. If the slab design is to be meet both, durability (Table 5.3) and loading minimum concrete strength requirements (Table 5.4), then the selected minimum concrete strength should be the higher of the two values.

<table>
<tr><th></th><th colspan="3">TEMPORARY STRUCTURE</th><th colspan="3">DESIGN LIFE 50 YEARS</th></tr>
<tr><td>Slab Loading</td><td>Minimum slab thickness (mm)</td><td>Minimum concrete strength (MPa)</td><td>Reinforcement</td><td>Minimum slab thickness (mm)</td><td>Minimum concrete strength (MPa)</td><td>Reinforcement</td></tr>
<tr><td>Cattle & quad bikes only</td><td>100</td><td>25</td><td rowspan="3">2.27 kg/m^2 or Mesh Type 665 (minimum of 30 mm from the top surface)</td><td>150</td><td>30</td><td rowspan="3">3.40 kg/m^2 or Mesh Type 663 (minimum of 30 mm from the top surface)</td></tr>
<tr><td>Less than 3 tonnes</td><td>125</td><td>25</td><td>150</td><td>30</td></tr>
<tr><td>3-10 tonne</td><td>125 -150</td><td>25</td><td>150</td><td>30</td></tr>
<tr><td>Over 10 tonne</td><td colspan="6">Design should be undertaken by a structural engineer with experience in the design of ground floor pavements</td></tr>
</table>

Table 5.4: Nominal Slab Thicknesses, Concrete Strength and Reinforcement for Typical Farm Loading Conditions – Developed from CCANZ IB 55

5.6 Crack Control

Cracks allow moisture and air to penetrate to the surface of the reinforcing steel, making it more susceptible to corrosion. Cracks allow water and aggressive chemicals to penetrate below the concrete surface exacerbating deterioration, such as freeze thaw and acid attack that would otherwise be limited to the concrete surface. Impact by stock and machinery will cause the crack edges to frit, widening the crack at the exposed concrete surface.

Therefore in an aggressive environment like a feed pad, cracked concrete will be less durable than uncracked concrete of the same mix design.

Cracks can harbour dirt and microorganisms, thus presenting animal hygiene issues and making the floor more slippery in the immediate area of the crack. They may also trap stones and other hard debris that then protrudes from the concrete surface, causing problems for stock and machinery.

Concrete shrinks as it hardens and dries. To accommodate this shrinkage and prevent wide, random cracking, careful reinforcement detailing and pre-formed or early cut joints are used. The joints must be in place before the concrete starts to shrink, no later than 24 hours after placing in summer or 48 hours in winter.

Reinforcing mesh will help to control cracking in larger slabs. Mesh should never be used without joints. Joints control the position of shrinkage cracks by introducing straight joints at predetermined locations. Joints need to be sealed with an appropriate sealant to stop moisture and solids getting into the joint.

Tables 5.5 and 5.6 descriibe types of joints, where and when they should be used.

FREE JOINT	A joint where horizontal movement is allowed for. The mesh reinforcement (or other reinforcement) is discontinued at the joint, which is connected horizontally with a de-bonded bar and allows for horizontal movement but prevents differential settlement.
TIED JOINT	A joint where the mesh reinforcement (or other reinforcement) is continuous across the joint that has a groove or saw cut one quarter (¼) of the overall depth at the surface (30 millimetres minimum). Note: where mesh is used it should be securely positioned below the base of the intended saw cut. After curing, a sealant should be injected into the cut to prevent subsequent moisture ingress into the joint. Sealant manufacturers will be able to identify suitable products to meet the hygiene and durability requirements of this environment.

Table 5.5: Types of Joints

SLAB SIZE	FREE JOINT	TIED JOINT
Slabs less than 20 metres in either direction	-	Every 5 metres
Slabs greater than 20 metres in either direction	At least every 20 metres (if less than 40 metres incorporate one free joint)	Every 5 metres (maximum of 4 bays)
For slabs that are not categorised as having to meet the *NZBC* and where reinforcement is omitted, joint spacing (free joint) should be reduced to 3 metre intervals.		

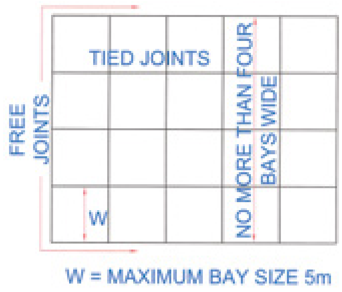

Table 5.6: Joints in Reinforced Concrete Slab

More information on joint options, layout and construction is available in CCANZ *IB55*, NZS 3604 and BRANZ guidelines.

Prestressed concrete may be used to minimise cracking without the use of joints, thereby avoiding the need for maintaining joint sealants. Cast *in situ* prestressed concrete slabs must be designed and constructed by specialist contractors.

Prestressed precast floor units are another alternative. Prestressed construction is more expensive than cast *in situ* reinforced concrete so is likely to be suitable only for large feed pads or where there is poor ground.

5.7 Reinforcement

As previously described, the primary function of reinforcing mesh in feed pad concrete slabs is for crack control. However, reinforcement also makes the slab more robust and less susceptible to severe deformation and break up. Slab reinforcement typically consists of mesh, supplemented with mild steel deformed bars of varying diameter and tensile strength around slab edges.

If reinforcement is not accurately positioned it will not function as intended. A feed pad slab placed on a well prepared surface is at greater risk from shrinkage cracking than from excessive loading. Therefore the mesh should be placed in the top third of the slab to control shrinkage cracking, rather than lower in the slab to control flexural cracking.

Chairs are used to raise the reinforcement to the required height. To protect the steel from corroding, the depth of concrete cover over the steel should be at least 30 millimetres, plus the depth of any proposed grooving. NZS 3101 specifies cover depths for different strengths of concrete.

As an alternative, fibre reinforcement may be used when loading conditions permit. Structural synthetic fibre reinforcement systems do not corrode and thus may be beneficial in feed pads. If fibres are to be used then fibres suitable for the loading and service conditions must be used. Structural fibres in this application must have the ability to bridge cracks without breaking. Professional advice should be sought when considering using fibre reinforced concrete (refer *CCANZ IB 39*). Note that steel fibres should not be used because if they protrude from the concrete surface they could injure stock.

5.8 Damp Proofing

Concrete will reduce water and water vapour rising up from the ground through capillary action, but is less effective if the water table is already high. Consequently, it is recommended that damp proofing be laid beneath all slabs that will house animals, be used for storing feed, or could have buildings on them, as it will reduce deterioration of materials in contact with the concrete. A damp proofing membrane generally consists of a layer of polythene sheet, at least 0.25 millimetres thick, placed under the slab. To be effective, damp proofing must be installed across the whole area and penetrations and laps taped to prevent the passage of moisture through them.

Damp proofing requires the same ground preparation as casting directly onto ground or granular fill. Section 6.1 describes the ground preparation necessary.

5.9 Design Guidance

In this Practice Note, Part 4: Concrete Structures provides further design guidance on aspects directly relevant to feed pads. Sections of particular interest are:

SECTION	ITEM
4.1.1	Specified Intended Life
4.1.2	Factors Affecting Durability
4.2.1	Cracking
4.3	Compressive Strength
4.4	Specifying Concrete
4.5	Placing, Finishing and Curing
5.1	Reinforced Concrete
7.3	Storage Structures
7.4	Foundations
7.5	Floor Slabs
7.6	Nib Walls
7.7	Surfacing

Table 5.7 Relevant Sections from Part 4: Concrete Structures

6.0 Some Key Construction Aspects

6.1 Site Preparation

Ground preparations for the concrete slab should include the following steps:

i) Remove all vegetation, rubbish, organic top soil and soft ground from the site. It may be necessary to dig out soft spots or excavate to a lower level to obtain "Good Ground" (see table 6.1)

Good Ground means any soil or rock capable of permanently withstanding an ultimate bearing pressure of 300 kPa (i.e. an allowable bearing pressure of 100 kPa using a factor of safety of 3.0), but excludes:

a) Potentially compressible ground such as topsoil, soft soils such as clay which can be moulded easily in the fingers, and uncompacted loose gravel which contains obvious voids,

b) Expansive soils being those that have a liquid limit of more than 50% when tested in accordance with NZS 4402 Test 2.2, and a linear shrinkage of more than 15% when tested, from the liquid limit, in accordance with NZS 4402 Test 2.6, and

c) Any ground which could foreseeably experience movement of 25 mm or greater for any reason including one or a combination of: land instability, ground creep, subsidence, (liquefaction, lateral spread – for the *Canterbury earthquake region* only), seasonal swelling and shrinking, frost heave, changing ground water level, erosion, dissolution of soil in water, and effects of tree roots.

Comment:

Soils (excepting those described in a), b) and c) above) tested with a dynamic cone penetrometer in accordance with NZS 4402 Test 6.5.2, shall be acceptable as good ground for *building* foundations if penetration resistance is no less than:

a) 3 blows per 75 mm at depths no greater than the footing width.

b) 2 blows per 75 mm at depths greater than the footing width.

Depths shall be measured from the underside of the proposed footing.

Table 6.1: "Good Ground" as defined by Compliance for New Zealand Building Code, Clause B1 Structure, Definitions

ii) If the ground is deemed not "good ground" it may be possible to excavate further to reach 'Good Ground' and then backfill. Otherwise, professional engineering advice should be sought

iii) Depending on the design finished level of the slab it may be necessary to replace unsuitable material with a compacted granular fill up to the required height (see table 6.2)

For a concrete slab, a layer of granular fill generally needs to be placed above the prepared subgrade, to raise the finished level of the concrete to the required height above ground level and to prevent storm and ground water being absorbed into the concrete. The granular fill should preferably have a well graded particle size distribution with a low percentage of fine clay and silt particles. Aggregates meeting NZ Transport Agency (NZTA) grading distribution requirements for M/4 AP 20 or AP 40 are suitable As a guide, granular subgrades will require 100 millimetres, whereas clay subgrades will need a much greater thickness. A typical maximum fill thickness is 600 millimetres with compacted individual layers of 150 millimetres thick

Table 6.2: Granular Fill Guide

iv) Compact the formation with a vibrating roller of sufficient capacity to achieve an effective allowable bearing pressure of more than 100 Kilopascals

v) Incorporate subsoil and perimeter drainage where necessary

vi) The ground surface (also known as the subgrade), should be compacted and levelled to provide a firm surface and drainage fall across the site

vii) The top of the granular fill should be as smooth as possible and may need to be blinded with sand or a fine aggregate to achieve this. An uneven surface will restrict movement of a slab as it dries and shrinks, and this could lead to unexpected concrete cracking

viii) Place the damp proofing membrane if one is to be used, OR

ix) Spray the finished ground surface with clean water so that it is adequately wet. If concrete will be poured directly onto the ground, spray the finished ground surface with clean water so it is adequately wet to avoid water being absorbed away from the concrete.

6.2 Concrete Placement

Section 7.0 of CCANZ's information bulletin *IB 55: Concrete for the Farm* provides very useful commentary on the process of placing concrete. Key points about good practices in concrete construction are highlighted below.

6.2.1 HOT AND COLD WEATHERING CONCRETING

If the concrete cannot be protected from freezing conditions for two to seven days after placing, it may become damaged by the formation of ice within the pore structure. In very hot weather or strong dry winds the concrete may stiffen prematurely leading to poor compaction and finishing. In hot dry conditions the concrete may also dry out too fast which can cause cracking and a reduction in strength gained as the hydration or hardening process can only occur in presence of moisture.

If it is necessary to mix and place concrete in either very hot or very cold weather, precautions must be taken to ensure that the concrete is not damaged or adversely affected by the ambient weather conditions. **Concrete should not be placed on frozen or dry ground**.

What is too hot or too cold? NZS 3109 (Concrete Construction) discusses a range of 5 to 30 degrees Celsius. Table 6.3 outlines CCANZ recommendations for concrete mix design and placement for temperatures below 5 degrees, or above 30 degrees Celsius. Note that the provisions for mix design are intended for ready mixed concrete, for which the supplier is responsible for all aspects of mix design.

ASPECT	IN HOT WEATHER	IN COLD WEATHER
Preplanning	▪ Preplan carefully to avoid delays at all stages ▪ Have standby equipment and manpower for all stages ▪ Pay particular attention to speed of application, effectiveness and duration of curing arrangements ▪ Schedule night time placement if possible.	▪ Preplan carefully to ensure adequate equipment and manpower available especially if there is a likelihood of temperatures below 0°C.
Concrete	▪ Use water reducing retarding admixtures in the concrete ▪ Reduce the temperature of the concrete by (in order of effectiveness): ▪ Reducing temperature of aggregates ▪ Using liquid nitrogen injections in the mixed concrete ▪ Reducing temperature of mixing water ▪ Using SCM to reduce heat of hydration ▪ Reducing temperature of cement.	▪ Reduce the setting time of the concrete by (in order of effectiveness): ▪ Heating mixing water (maximum 70°C) ▪ Using (chloride-free) accelerating admixture ▪ Using higher cement content ▪ Using high-early-strength cement.
Batching, mixing and transporting	▪ Shade batching, storage and handling equipment or at least painting with reflective paint ▪ Discharge transit mixer trucks as soon as possible.	
Placing and Compacting	▪ Shade reinforcement, formwork and subgrades if possible and spray with water ▪ Ensure that slabs have minimum “fronts” to which concrete is added ▪ Place concrete in walls and deep beams in shallow layers ▪ Use burlap covers if there is any delay between load deliveries.	▪ Thaw frozen subgrades and heat frozen forms (particularly steel) before placing concrete ▪ Warm, insulate or enclose handling and placing equipment. ▪ Avoid delays in handling and placing.
Finishing and Curing	▪ Use sunshades and windbreaks to lengthen finishing time (or, if hot/dry winds present, to control plastic shrinkage cracking) ▪ For flatwork, use aliphatic alcohol after initial screeding if hot/dry winds present ▪ Use revibration to correct plastic shrinkage cracking ▪ Use water curing as the preferred method for at least 24 hours	▪ Maintain concrete temperature until safe strength reached by means of form insulation, insulated covers or heated enclosures ▪ Delay striking of formwork for as long as possible ▪ Avoid thermal shocks and temperature variations within a member. This includes not using cold water for curing, and removing protective measures gradually.

Table 6.3: Controlling the effects of hot and cold weather - CCANZ website, Technical Information,
http://www.ccanz.org.nz/page/Hot-and-Cold-Weather-Concreting.aspx

6.2.2 COMPACTION

Once in place, concrete must be compacted to remove large air voids which would otherwise weaken it. Pumped concrete must be compacted even though it may appear because of its high workability to be well consolidated when placed. Concrete floors that are subject to corrosive substances or abrasion, like feed pads, must be compacted with a mechanical vibrator. A vibrating screed is best for floor slabs but an immersion poker vibrator will be required around the perimeter of the screeded area.

6.2.3 FINISHING

Floor slabs are finished in four stages.

Stage	Activity
1	Screeding to provide the correct level
2	Smooth the surface with a float
3	Leave the concrete to bleed
4	Densify the surface by trowelling

Table 6.4: Finishing Stages

Because feed pads are subject to corrosive attack by FDE and leachate from the feed, they must be worked with a steel trowel into a hard dense surface. While trowelling at repeated intervals will increase the hardness and durability of the surface, it will also produce a smooth and very slippery finish. In this Practice Note, options to improve the slip resistance are include in Part 4 section 7.7.2.

6.2.4 CURING

Concrete hardens and gains strength by chemical reaction between water and cement, not by drying. Therefore it must be cured to prevent loss of moisture. Curing must start as soon as possible after the final stages of concrete finishing. If proper curing is omitted in an attempt to save money, the concrete will not achieve its required strength or durability. Feed pads in relatively abrasive environments must be cured for at least 7 days after casting (see table 5.3). Curing for at least three days may suffice for feed pads in less aggressive conditions. Typical curing options are as follows.

Water cure	The entire concrete surface is kept continuously wet by ponding, mist spray or sprinkler.
Polythene cure	The surface is wetted and covered with polythene, the edges of which are tightly secured and sealed to prevent moisture loss.
Curing compound	Apply a proprietary curing compound complying with AS 3799 in accordance with the manufacturer's specifications.

Table 6.5: Curing Options

Feed pad under construction
(Note in the foreground the flood washing pipe outlets built into the slab structure)

To prevent early age shrinkage cracks from appearing, it is recommended that the joints are formed on the day of the pour as changes in temperature overnight may lead to early cracking.

7.0 Effluent Management

7.1 Feed Pad Effluent

Feed pad effluent is different to normal dairy shed effluent in the following ways:

- It has a higher solid content, due to feed wastage being combined with dairy effluent during cleaning and a higher fibre diet
- Contains a greater amount of fibrous material
- Feed pad effluent has a higher nutrient content than farm dairy effluent
- Nutrient content is affected by feed type and feed quantity. Different feeds have different nutrient concentrations; effluent will reflect these nutrient variations. The quantity of feed offered or the percentage of the diet supplemented on the pad also reflects in the nutrient content of the effluent.

Effluent planning is a key component in feed pad design, and must be considered during the design stage and integrated into the structure at construction time. Designing and retrofitting an FDE system to a new feed pad after construction will tend to result in a less than optimal system as well as being more expensive than it might otherwise have been.

Factors to consider when designing a feed pad are listed in table 7.1.

- All effluent produced on feed pads must be contained and directed into a specifically designed FDE system for the site that includes storage
- Maximise the difference in levels between FDE system components to provide gravity flow of effluent, ground and storm water
- Consider using passive or mechanical separation methods to remove solids before irrigating to pasture
- Existing sludge beds and anaerobic ponds, if used, will need desludging more regularly
- Scraping of sealed surfaces will reduce the volume of water required for cleaning
- A feed pad represents a large surface catchment area capturing stormwater that can enter the FDE system
- Install a mechanism to divert clean stormwater off the feed pad area when not in use
- Consider using a chopper pump in the feed pad effluent holding sump to reduce the fibre size of solids and hence incidence of downstream blockages.

Table 7.1: Effluent System Design Recommendations for Feed Pads

FDE from feed pads can be treated using many different methods and depends on factors such as the farm layout and other infrastructure present. Figure 7.1 below graphically shows typical FDE systems that can be used with feed pads.

The farm's existing effluent system may need to be modified if the proportion of solids in feed pad effluent is substantially higher than that of dairy shed effluent. For example, some changes to the solids separation system may be required. Solids separation systems function optimally at differing percentages of dry matter (in solids by mass). Part 2: Solids Separation section 3 of this Practice Note details the more common types of separation methods available.

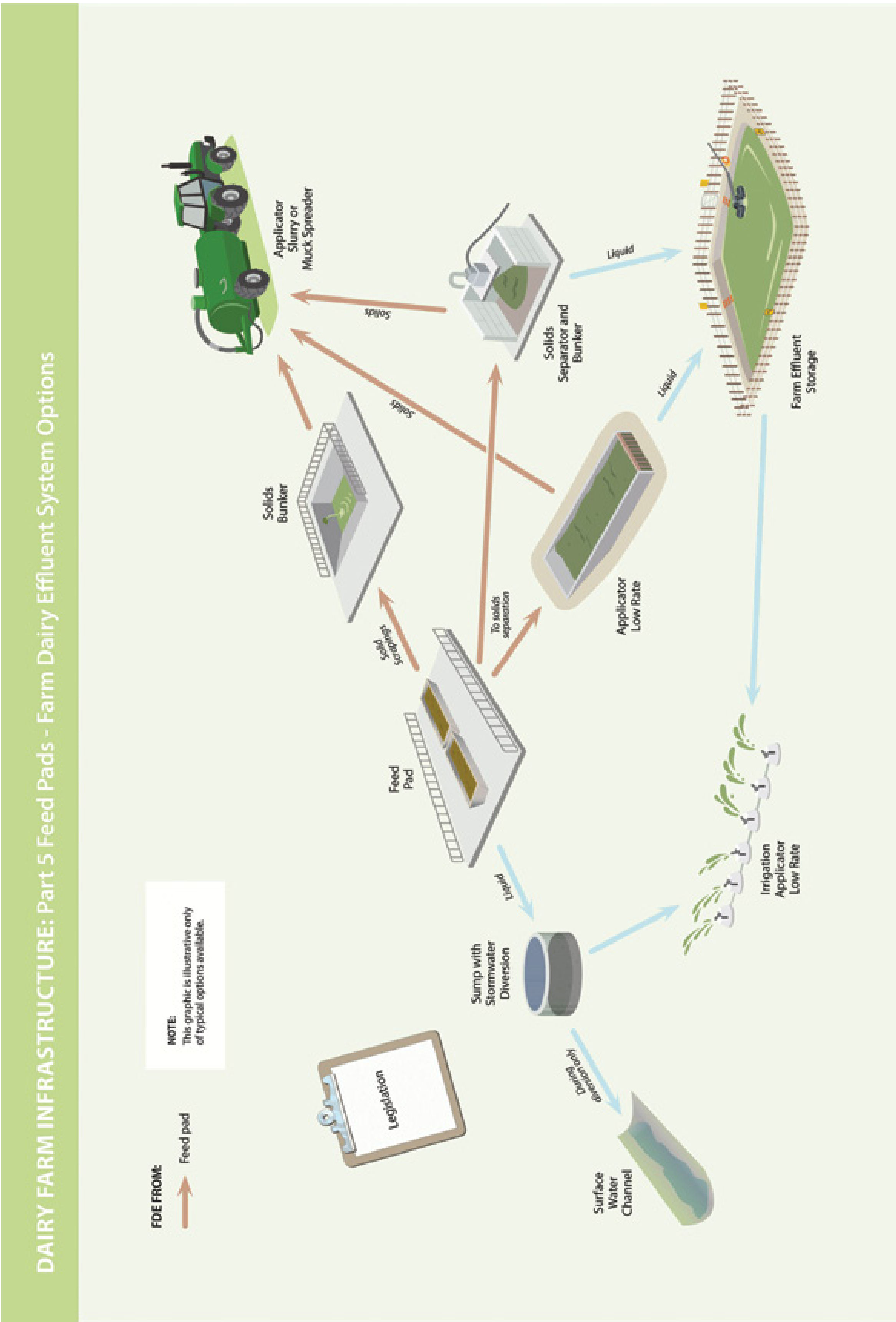

Figure 7.1: FDE System Options for Feed pads

7.2 Cleaning

Any feed pad design developed must incorporate provision for the intended cleaning process.

Cow lane surfaces can accumulate FDE along with muck transported in and require regular cleaning. Options for removing FDE and cleaning the concrete surface are listed in Table 7.2 below. The preferred method at a given time will be determined by the availability of water and staff.

CLEANING METHOD	ADVANTAGES	DISADVANTAGES
Scraping: Use a 2-to-3-metre-wide blade fitted to a quad bike or smaller tractor. A sprinkler system to pre-wet the concrete can assist.	▪ Lower capital cost ▪ Solid effluent easier to handle than liquid ▪ Relatively quick clean up.	▪ Some labour cost
Scraping and Draining: Solids are scraped up slope into a bunker at the top end of the feed pad while the liquids gravity drain into a sump at the bottom end.	▪ Provides an initial separation into solids and liquid parts which can each be treated differently.	▪ Some labour cost
Hosing: Hand held hosing from several hydrants around the pad.	▪ Low capital cost.	▪ Higher labour cost ▪ Splashing of feed area ▪ High volume of FDE generated.
Flood washing: A high volume/low pressure deluge cleaning system, typically a pipe riser from a stored water supply. Drainage divided into multiple channels to aid washing.	▪ Lower labour cost ▪ No splashing feed area ▪ Can accommodate green water reuse.	▪ Higher capital install cost ▪ High discharge rates (12 to 15 m^3/min) ▪ Large volume of FDE generated (if cleanwater used)

Table 7.2: Clean Down Options

Scraping

Flood washing

Feed bins must be regularly cleaned so that food quality is maintained. Regular dry scraping of feed bins is usually sufficient along with washing down as and when required. Holes through the end of the lowest bin will assist with drainage.

7.3 Greenwater Reuse

Green water reuse, also known as green water recycling, is where FDE that has been mechanically or passively separated is pumped back and stored alongside the feed pad for use in wash down.

Unlike dairy sheds, *NZCP1: Design and operation of farm dairies – Code of practice*

Section 8.9 allows dairy yards and feed pad surfaces to be cleaned using reused separated effluent water. Recycled effluent water must not be used to clean feed bins or lanes. Tanks, pipework and hoses used for greenwater must be clearly identified to prevent greenwater mistakenly being used for structures in contact with stock feed.

Whatever wash down option is selected there are advantages in adopting reused greenwater for feed pad wash down water. This approach reduces the volume (and cost) of:

- Fresh water that needs to be supplied to the farm
- Deferred storage of FDE required
- FDE to be irrigated to pasture

7.4 Storage Calculation

FDE captured from a feed pad needs to be retained in a pond or tank until soil conditions are suitable for disposal through pasture irrigation. This containment is known as deferred FDE storage.

As the total volume of FDE captured on the farm will increase, from rainfall, wash down water and excreted material from the feed pad, a check needs to be made to confirm that sufficient deferred FDE storage will be available on the farm.

The DairyNZ document How to use the *Dairy Effluent Storage Calculator (DESC)* provides details on how feed pad information can be entered into this purpose designed program along with that from the rest of the farm. In particular, the DESC information sheet (Page 7) provides a handy table to record data, while page 18 gives guidance on how the data can be inserted into the DESC software.

Enter feed pad wash volumes under the **Catchments** tab. This is where the feed pad area and diversion (if used) dates are also inserted. Then, select the **Wash Water** tab and under **Feed pad Wash Volumes** enter the average daily cow numbers, average daily hours on pad, and average daily wash volume values.

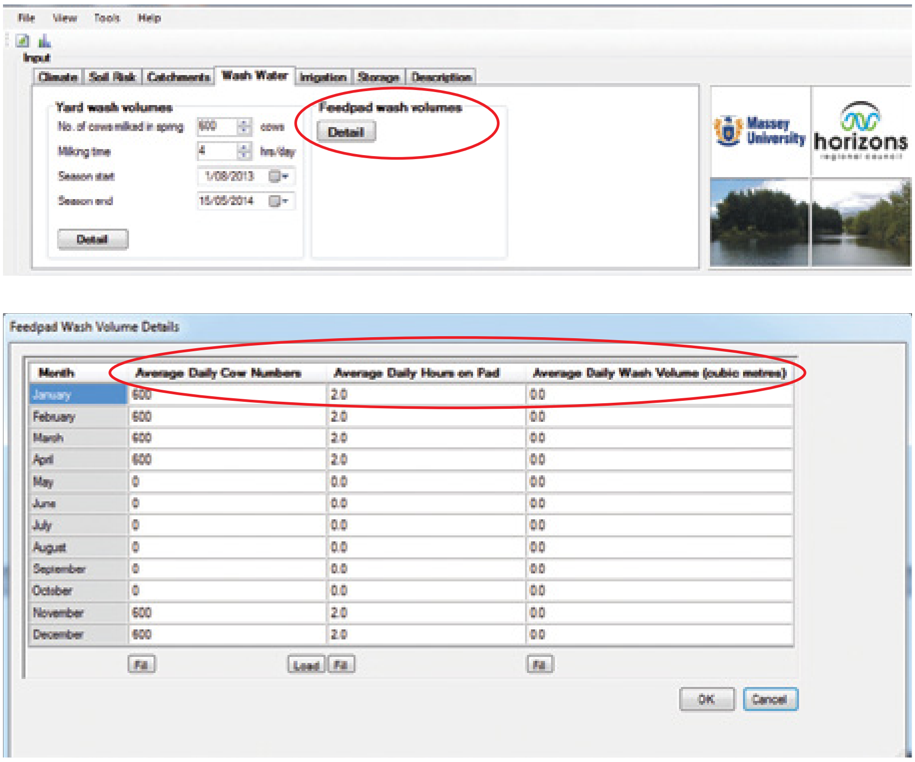

Figure 7.2: Dairy Effluent Storage Calculator Inputs