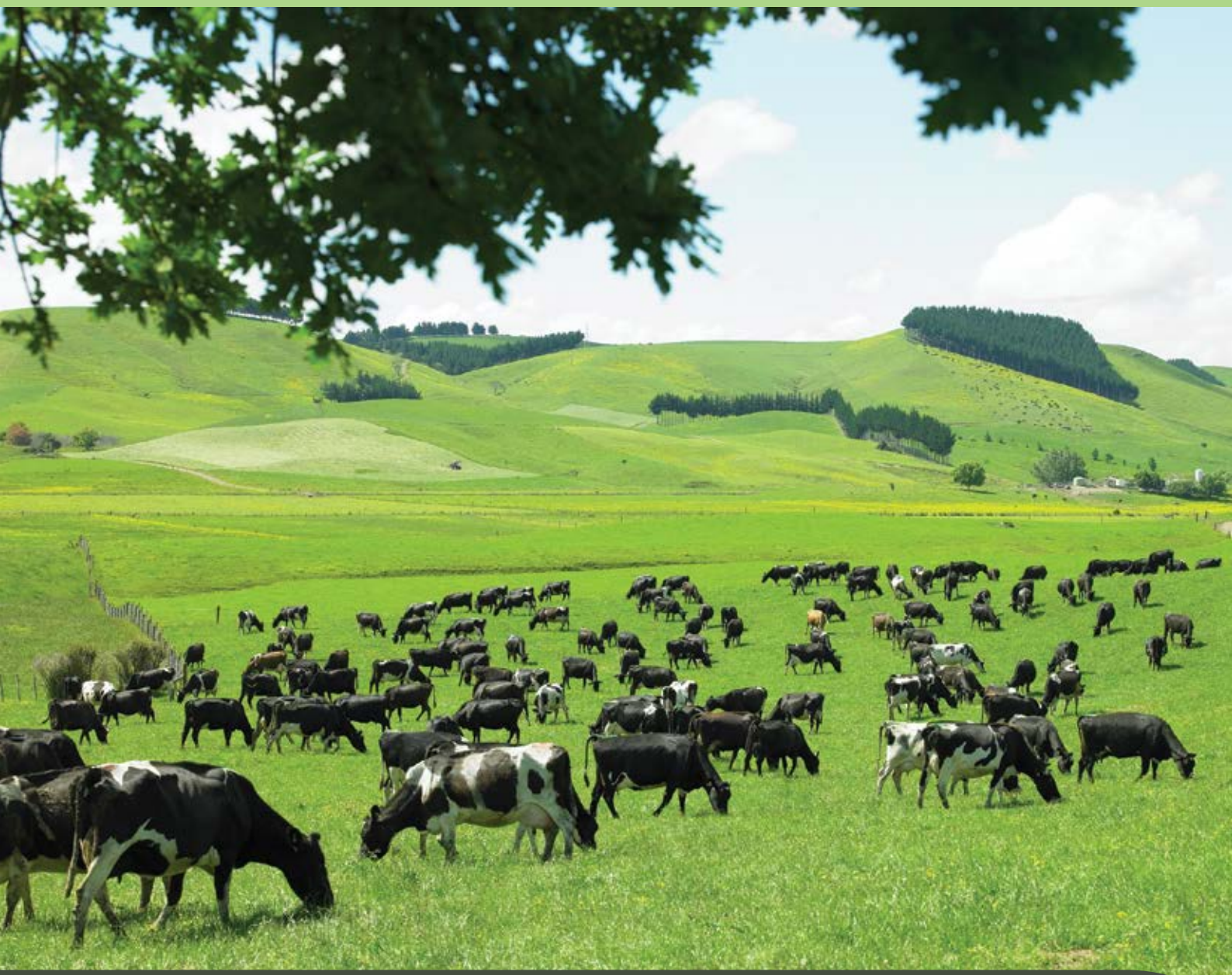
Nutrient management on your dairy farm

A farmer's guide to understanding how nitrogen and phosphorus enter, cycle through and leave your dairy farm



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About this booklet

The National Policy Statement for Freshwater Management (NPS), which was issued by central government in 2011, now requires that all regional councils set quality limits on all ground and surface water bodies within their region by December 2030.

For farmers, this means that water quality limits will be set over the next few years, and some farmers may have to alter their current management plans to meet them.

While we do not know what the limit will be or when it will be implemented, we do know that they will target nutrient losses from land – predominantly nitrogen and phosphorus. When nitrogen and phosphorus are lost from farmland to water bodies, increased growth of weeds and algae can occur. Water then becomes restricted in its value for recreation, culture and other land uses.

There are a number of things that you can do now to prepare and make your business more resilient to any future regulatory changes. This booklet aims to provide you with knowledge to help you to do this.

Reading this guide will help you understand:

1. How nitrogen and phosphorus cycle in a farm system and how they can be lost from your farm into water. Faecal and sediment losses, which can also impact water quality, are discussed.
2. What water quality means and the significance of different water bodies and catchments to water quality.
3. Where the nutrient hotspots are on your farm.
4. What tools are available to help you measure and manage nutrient use on your farm.
5. What you should focus on to improve nutrient use on your farm.

This guide also includes:

- key messages for reducing nitrogen leaching and improving nitrogen conversion efficiency
- where to go for more information.

In this resource a water body refers to anything that holds water, whether water is:

- **Still:** lake, wetland, on-farm dam, pond
- **Flowing:** stream, creek, river
- **Manmade:** drain
- **Intermittent:** only holds water in wet periods or over the winter
- **Underground:** sub-surface e.g. aquifer

Nitrogen and phosphorus

Nitrogen (N) and phosphorus (P) are only two of many nutrients that are essential to plant growth and function. When applied strategically, they increase pasture growth. Conversely when these and other nutrient levels are low (limiting) in the soil, it is becomes difficult for a plant to complete its normal life cycle.

The input of N and P to a water body can have serious impacts on water quality, and there is growing social and regulatory pressure to address these impacts. For that reason this booklet will focus on these nutrients.

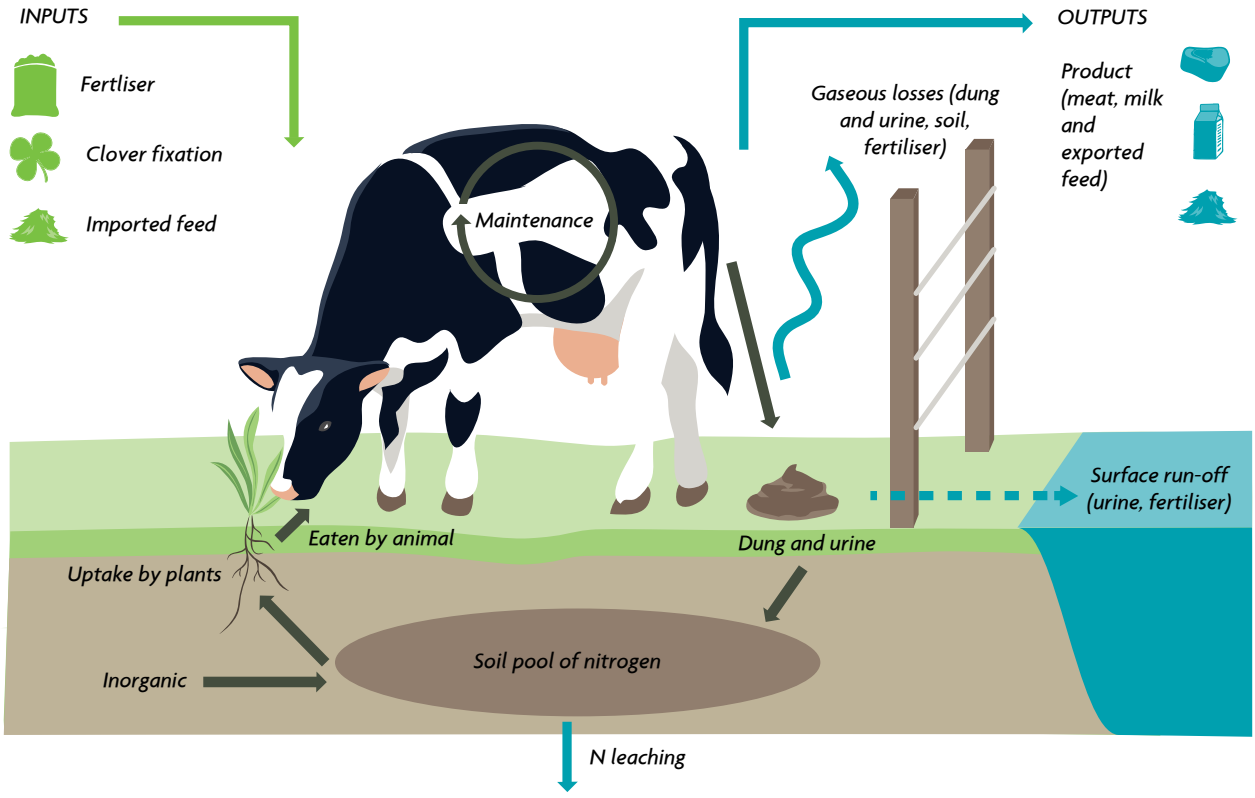
Understanding the N and P cycles, and how the nutrients can move from farmland into water bodies, is an essential first step to managing these nutrients efficiently on your farm.

Nitrogen (N)

N is a chemical element which is present in all living cells and has a major effect on plant quality and growth potential. However, when N is converted to nitrate in the soil it becomes mobile (active). Nitrates have the ability to cause negative impacts on the environment if not taken up by plants.

Knowing how N enters and moves through a dairy farm system will help you to understand where it can potentially be lost to the environment, e.g. air or waterways, as shown in the diagram below.

Simplified nitrogen cycle



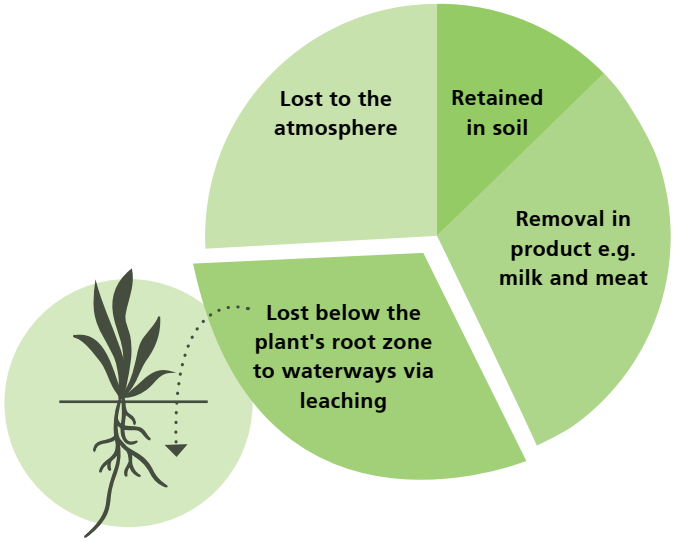
N is continually cycling through the soil, atmosphere and the farm system.

Approximately 30% of the N eaten by a cow is converted into milk and meat. A small portion is lost to the atmosphere as a gas.

A significant proportion of the N excreted from the cow will be returned to the soil (into the soil pool) as plant residues or as dung or urine. In the soil pool, N is converted into forms that are available for plants to uptake.

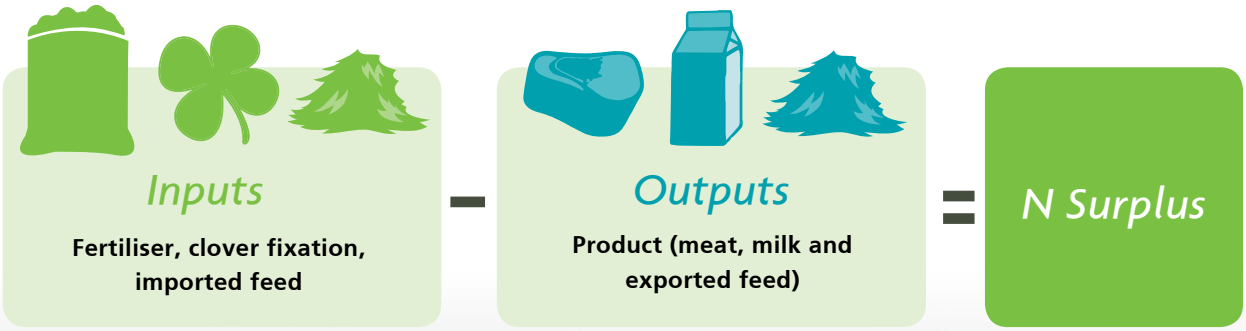
Where nitrogen ends up after entering a farm system

The exact breakdown of where N goes after it enters a farm system will vary between farms and paddocks. A large proportion is lost beyond the root zone to water via a process called 'leaching'. Urine patches are a significant source of N leaching.

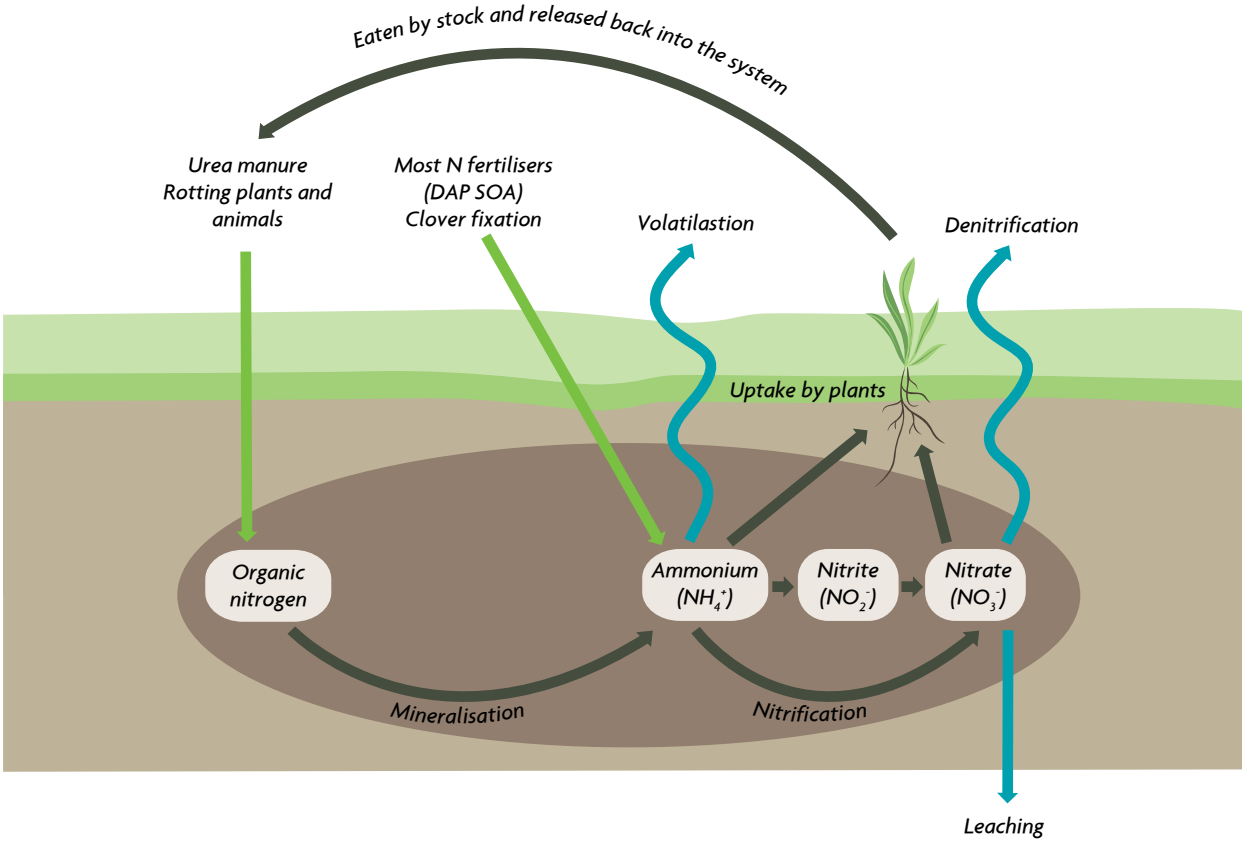


N surplus

N surplus is what remains after the conversion of N inputs to saleable product e.g. milk, meat or feed.



How nitrogen is converted to nitrate



Mineralisation (organic nitrogen to ammonium)

Organic nitrogen is the N contained within organic matter such as animals, plants, dung and urine. Plants cannot use organic N until it has been broken down into a mineral form of N (ammonium). This is done by microbes in the soil and the process is called mineralisation.

Nitrification (ammonium to nitrate)

Nitrification is the process by which bacteria in the soil transform ammonium to nitrate through the addition of oxygen (oxidisation). Nitrification occurs all year round in most New Zealand soils. This generally means that N does not stay in the soil in large quantities as ammonium or nitrite before being converted to nitrate.

Nitrate leaching

Nitrate is mobile and highly soluble. It can be readily leached if there is too much available in the soil for the plants to take up. Leaching is the downward movement of soluble nitrate through the soil with water (drainage). If this happens, during conditions favourable to leaching, nitrate may be lost below the plants root system, through the soil profile to groundwater.

Volatilisation and denitrification

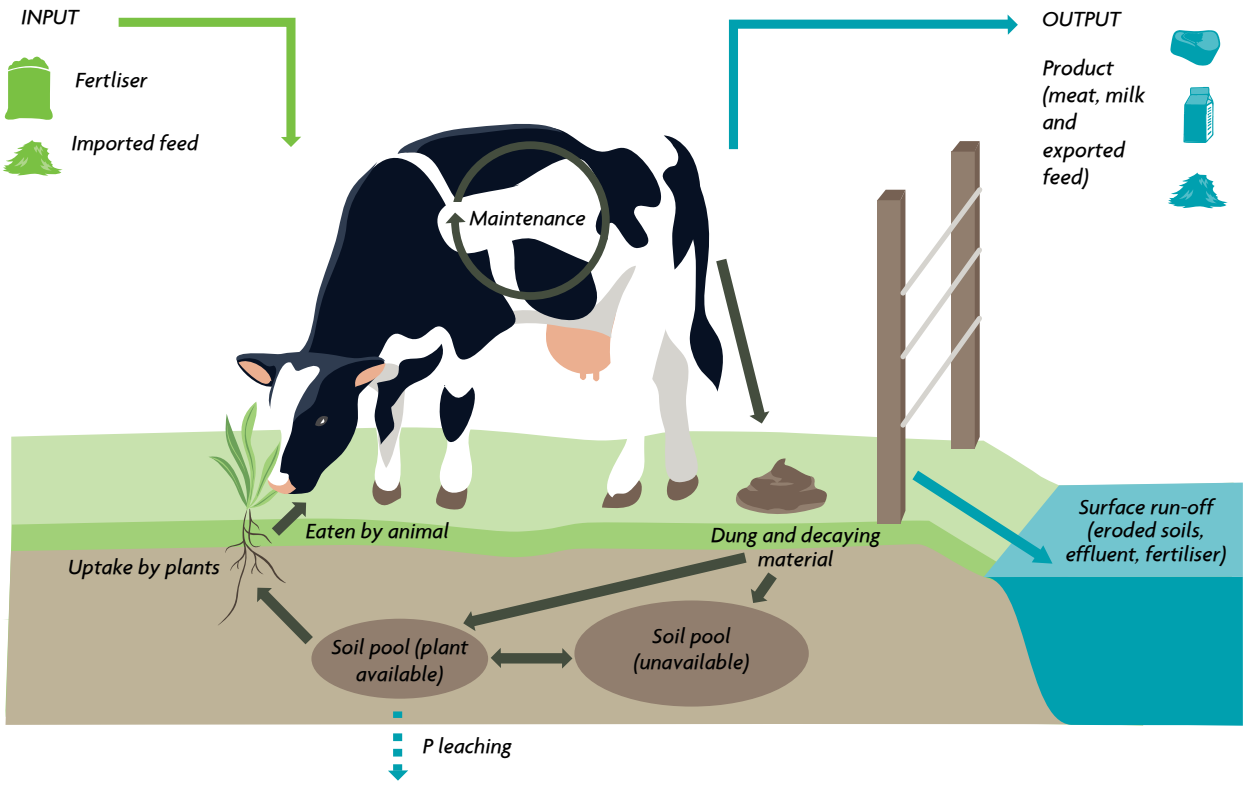
Volatilisation and denitrification are the processes by which N is lost to the atmosphere as a gas (ammonia, nitrous oxide or nitrogen gas). Denitrification occurs in wet or waterlogged soils (e.g. in winter) and volatilisation tends to occur during drier warmer conditions (e.g. spring, summer and autumn).

Phosphorus (P)

P is another chemical element used in plant and animal growth. It readily attaches to soil and organic particles and therefore, unlike N, only a small amount is leached. Instead it is primarily lost from farmland when soil bound with P particles is eroded, caught up in overland flow and runs off into water bodies.

Knowing how P enters and moves through a dairy farm system will help you to understand where it can potentially be lost to the environment, e.g. waterways, as shown in the diagram below.

Simplified phosphorus cycle



P is typically added to a dairy farm system via fertiliser and imported feed as phosphate. Phosphate is the form of phosphorus that can be taken up by plants.

Of the phosphate eaten by the cow in grass or supplements, approximately 30% will leave the system in products such as milk and meat. The remainder will be excreted by the cow as dung.

Because phosphate is relatively insoluble and attaches strongly to soil particles, a large proportion of the P added to the system will be retained or 'fixed' to soil particles. Therefore, activities which disturb soil can also contribute to losses of phosphate via erosion and surface water runoff. P is also lost by direct deposition or runoff of dung, fertiliser or farm dairy effluent to waterways. A very small proportion is leached.

Where phosphorus ends up after entering a farm system

Relative to N, only a small proportion of P is lost or transferred to waterways.

While this may not look too concerning, this small amount can have damaging impacts on the quality of the receiving water body.

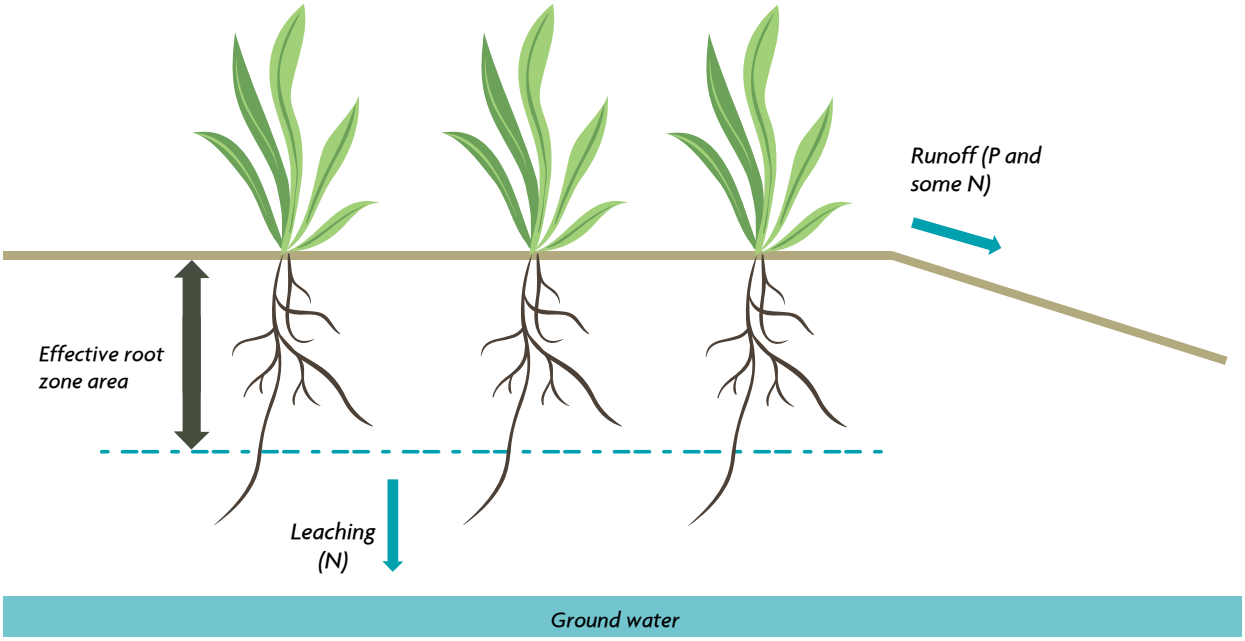
Phosphate losses are closely linked to sediment and faecal matter

P tends to bind to soil particles (sediment) and dung and farm dairy effluent contain high levels of P. Therefore losses of P on dairy farms are closely linked to losses of sediment and faecal matter.

How nutrients are lost to water bodies

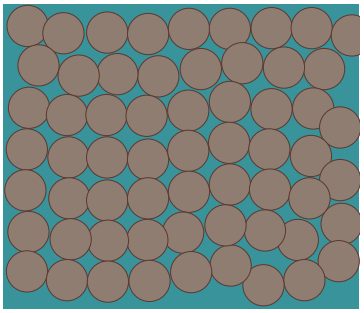
The main loss pathways for N and P to a water body are different. N is typically leached to groundwater and over time will reach surface water. Because P attaches to soil particles it is more commonly lost via runoff to surface water.

Loss pathways for nitrogen and phosphorus are different



Nutrient loss is influenced by soil type: clay versus sandy soils

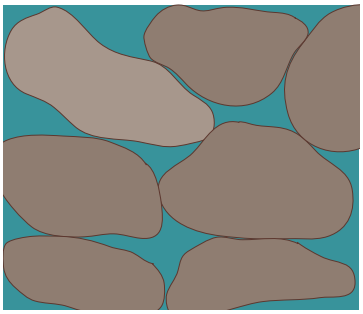
Soils vary greatly in the amount of water they can store in the gaps between individual soil grains (known as the water holding capacity). This structure determines if the nutrients are likely to run off or leach.



Clay soils have smaller pores. They hold onto water tightly - but they cannot hold a lot of water.

It is harder for water to infiltrate through a clay soil and runoff is more likely to occur.

These tend to be the poorly drained soils on your farm.

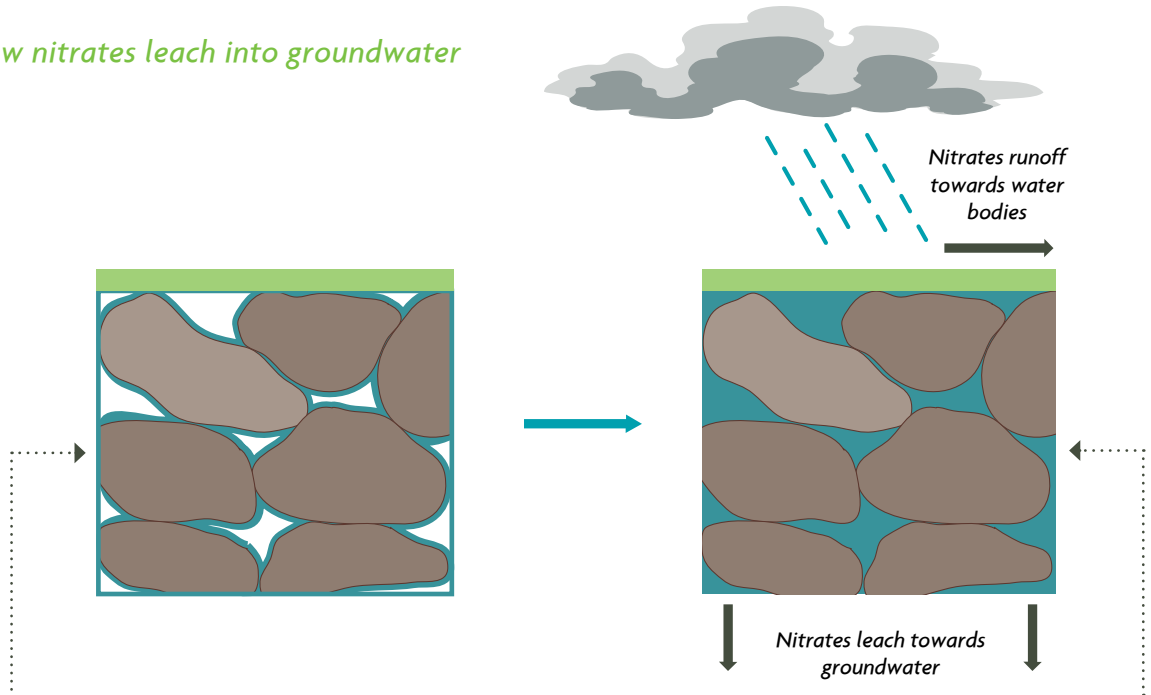


Sandy soils have bigger pores. They can hold onto more water but not as tightly as clay soils.

It is easier for water to infiltrate through a sandy soil and leaching is more likely to occur.

These tend to be the free draining soils on your farm.

How nitrates leach into groundwater



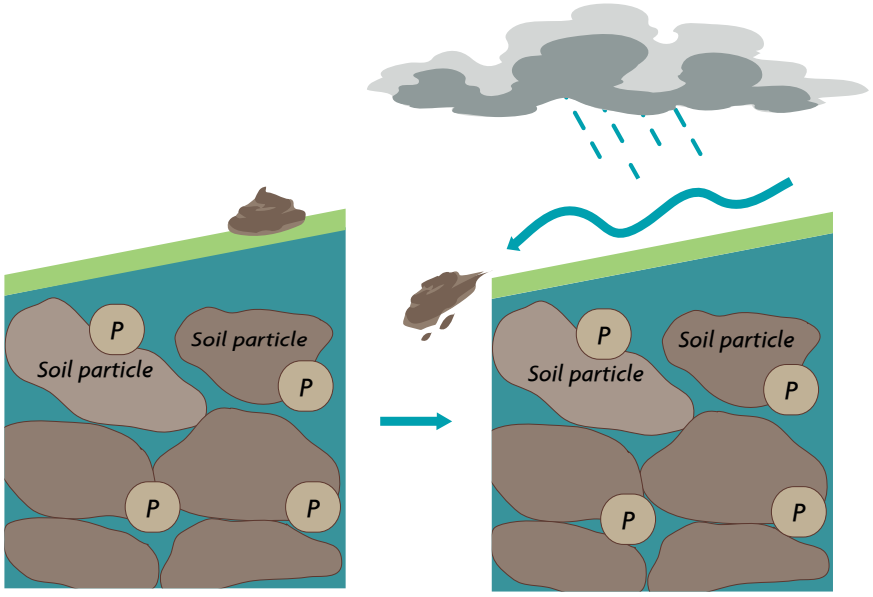
- Soil is not at water holding capacity. There is a mix of water and air in the soil pores.
- Nitrates are dissolved in soil water but not moving.
- Nitrates are available for plant uptake.

- Water (rain, irrigation) increase soil water above the soil water holding capacity. This means the soil cannot hold any more water.
- Gravity causes the soil water (and the dissolved nitrates it contains) to leach towards groundwater.

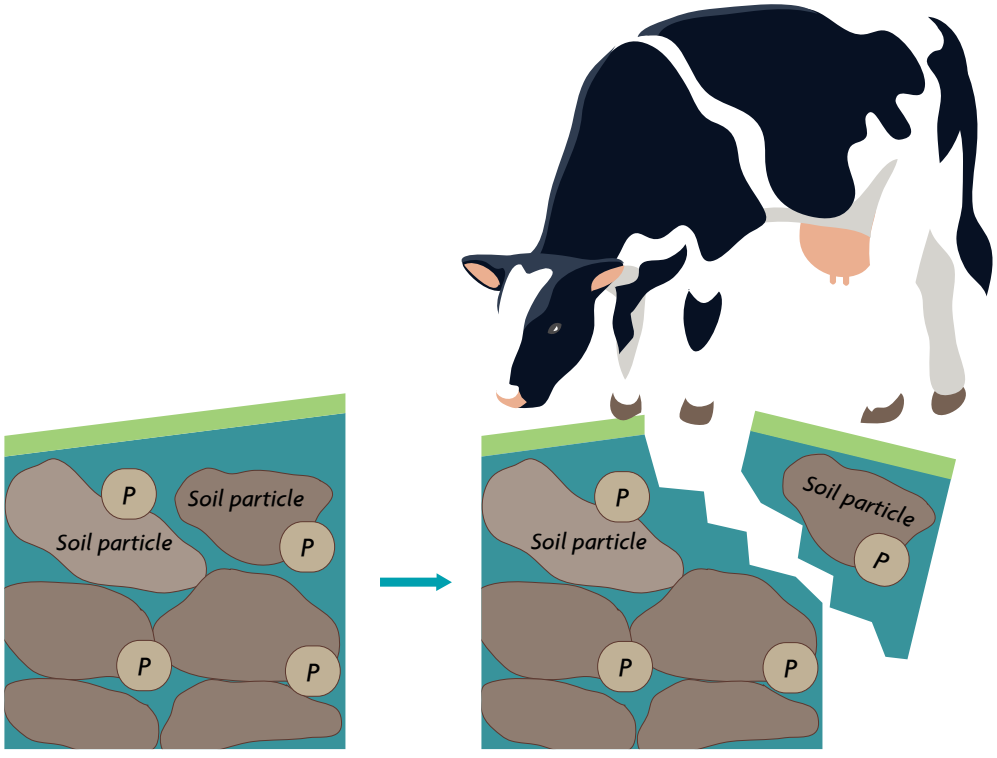
How phosphates runoff into surface water

There are two key ways that P is lost from dairy land to water:

1. **Overland flow** – when dung, fertiliser or farm dairy effluent are applied on land with a slope the risk of them running off into water is increased, particularly if in rains shortly after.



2. **Erosion** – P is sticky and binds to soil particles. Any activities that disturb the soil, such as pugging, cultivation or erosion, cause losses of soil particles and therefore losses of P.



Increased applications of P (fertiliser or effluent) may result in more P being bound to each soil particle. This increases the amount of P that is at risk of running off to water.

Action

Knowing your farm's soils and their drainage qualities is important as this influences how much nitrate and phosphate may be lost to the environment. Most farms have multiple soil types on their property; therefore the risk of nutrient losses will vary across and between farms.

Do you know what the soil types on your farm are, where they are located or how well they drain?

- Visit the S-map online website which is a database of soil types in New Zealand **smap.landcareresearch.co.nz**
- Talk to your regional council, they may have their own soil maps.
- Ask your nutrient management advisor (e.g. fertiliser representative or farm consultant) about getting your soils mapped.
- Consult a soils expert: a list of experts can be found on the New Zealand Society of Soil Science website: **nzsss.science.org.nz**

Impacts of losing excess nutrients to waterways

Sources and potential impacts of excess phosphorus (P) and nitrogen (N)

	Source on farm	Potential impacts on waterways	Potential impacts on your farm
P	• Dung from stock. • Phosphate in fertiliser. • Farm dairy effluent. • Soil sediment.	• Promotes nuisance aquatic plant and algae growth in waterways which degrades water quality, blocks water intakes and makes water unpleasant for recreational activities and drinking.	• Loss of income through inefficient use – having to increase fertiliser application to compensate for lost N and P or letting valuable nutrients in effluent go to waste. • Excess plant growth in streams can increase the frequency of flooding and erosion, this comes at a cost when it wipes out fences, riparian plants and introduces weeds onto pasture. • Water taken for milk cooling may need increased treatment if water quality parameters are degraded (such as temperature); this has associated costs. • Degraded water quality from bad environmental management can negatively impact on international markets and reduce the value of New Zealand milk products.
N	• Urine and dung from stock. • N in fertilizer. • Farm dairy effluent.	• Promotes nuisance aquatic plant and algae growth in waterways which degrades water quality, blocks water intakes and makes water unpleasant for recreation and drinking. • Ammonia (a form of organic N) can be toxic to fish and stream insects (fish food). • High concentrations of nitrates in groundwater used for drinking poses a significant health risk.	

Impacts of losing excess sediment and faecal matter to waterways

Losses of P are closely linked to losses of sediment and faecal matter to water bodies. This is because P tends to be bound to the soil particles in the sediment or sourced from dung. Therefore, if you have issues with too much sediment or faecal matter in water, you may also have issues with too much P.

Faecal matter also has other water quality implications which are explained in the following table. It is very likely that central government will require regional councils to set limits around faecal matter concentrations in all New Zealand water bodies to amounts that allow secondary contact recreation activities (which includes activities such as fishing and tramping) to still occur.

Sources and potential impacts of excess sediment

Source on farm	Potential impacts on waterways	Potential impacts on your farm
• Slips and hillside erosion. • Pugging and trampling. • Surfaces of tracks, races and paddocks.	• Degrades water quality and clarity which makes water unsafe for swimming. • Excessive sediment can smother the stream bed, reducing habitat for insects and fish. • Excessive sediment can reduce visual feeding efficiency for fish. • Excessive sediment can clog fish gills which suffocates them.	• Excess sediment in streams, which tends to settle on the inside of bends, can: - affect flow and cause flooding, - destabilise and increase erosion on the outside bends worsening the issue, - impact on the ability of the drain to function which can lead to flooding. • Excess sediment indicates there is erosion somewhere on your property; this will mean increased repair and maintenance costs e.g. on scoured races, hillsides and banks. There are also potential vet or stock loss costs from injury or lameness caused by these areas.

Sources and potential impacts of excess faecal matter (and other bacteria)

Source on farm	Potential impacts on waterways	Potential impacts on your farm
• Dung from stock. • Farm dairy effluent irrigation.	• Human health risk from swimming and drinking. • Stock health risk if present in stock water.	• Water taken for human or stock drinking or milk cooling may need to be treated if there is excess faecal matter or other bacteria.

Freshwater quality

New Zealanders enjoy freshwater which, by international standards, is abundant and clean. Water is essential to sustain human, plant and animal life. It provides pleasure and recreation as well as supporting much of New Zealand's economic growth and development. However, water does not always fall when and where we want it, and while it is plentiful, it is not unlimited.

There are a number of areas throughout the country where water quality is degrading beyond what is acceptable for ecosystems to function normally, for people to meet their recreational and cultural needs, and for sustainable economic development.

This section provides you with insights into:

- water quality and how we measure it
- the relationships between the different water bodies in a catchment (e.g. farm stream to the sea)
- how the natural characteristics of water bodies, such as flow, influence the impact of excess nutrients and sediment
- how these principles are important as they underpin how regional councils will set water quality limits or targets in your catchment.

Water quality: what does it mean?

Water quality is a description of the condition of the water. It includes measurements, using proven scientific methods, of physical, chemical and biological parameters.

There is no single definition for what is 'good' or 'bad' in terms of water quality. To determine what is good or bad we need to consider:

- what are the parameters of the water?
- what is the water used or valued for?

When setting water quality limits both parameters and values are considered.

Parameters of water

Physical parameters

How clear the water is, which is a measure of sediment in the water.

Chemical parameters

How much N and P are in the water.

Biological parameters

How many living things are in the water, including bacteria.

Values and uses of water

In New Zealand water values typically include:

- ecosystem health and biodiversity
- cultural values whether Maori or Pakeha
- recreational values including primary contact (swimming, water-skiing, kayaking) and secondary contact (fishing, tramping)
- amenity values such as landscape and scenic values
- health values including stock and human drinking water
- economic values such as irrigation water and hydro power generation.

Not every water body has the same values. A farm drain, which we value for its ability to remove water, does not have the same values as Lake Tekapo, which we value for its ability to create hydro-electricity.

However, even farm drains have values and characteristics around drainage, that can be threatened by inappropriate land management.

Water quality limits

Water quality limits take into account both the values or use of the water and the parameters required for the values to occur. A water quality limit is then set at a 'point' (or number) that balances agreed community values with the significance of the impact on the values.

Values or use of the water + **Parameters required for values/use to occur** = **Water quality limit**

What are the water quality limits in my region?

The National Policy Statement for Freshwater Management (NPS) requires that regional councils set quality limits on all water bodies by 2030.

Currently for the majority of New Zealand waterways, no water quality limits have been set. However this is likely to change over the next few years.

How will the water quality limits be set?

Central government has made it clear that they want to actively engage local communities, to determine which values to protect and what level of protection is needed.

Engagement and consultation means that you and your community can play a pivotal role in protecting your waterways and farm systems.

Everyone in your community, including stakeholders with competing needs, will be able to sit down together and work out what's best for the catchment while satisfying the particular circumstances of local users. This should result in more agreement and reduce the chance of highly restrictive legislation.

Agreed community values

Significance of the impact on the parameters of the water

Action

How can I get involved in the consultation process?

- Call your regional council catchment management officer to find out when consultation is happening in your catchment.
- Keep an eye on local papers, regional council websites and for fliers in your letter box telling you about relevant information nights.
- DairyNZ is already advocating in some areas. Visit **www.dairynz.co.nz/advocacy** for more information.

All water in a catchment is connected

A catchment is an area of land, bound by hills or mountains, from which all water running over the land (runoff) flows to the same low point. This low point could be a lake, dam, river or the mouth of a river where it enters the ocean. A catchment also includes groundwater, storm water, wastewater, and water-related infrastructure.

The diagram below illustrates how a catchment forms a main river. Surface water runoff flows into the tributaries which begin as small creeks and drains. They flow into larger streams which then flow into the main river stem.

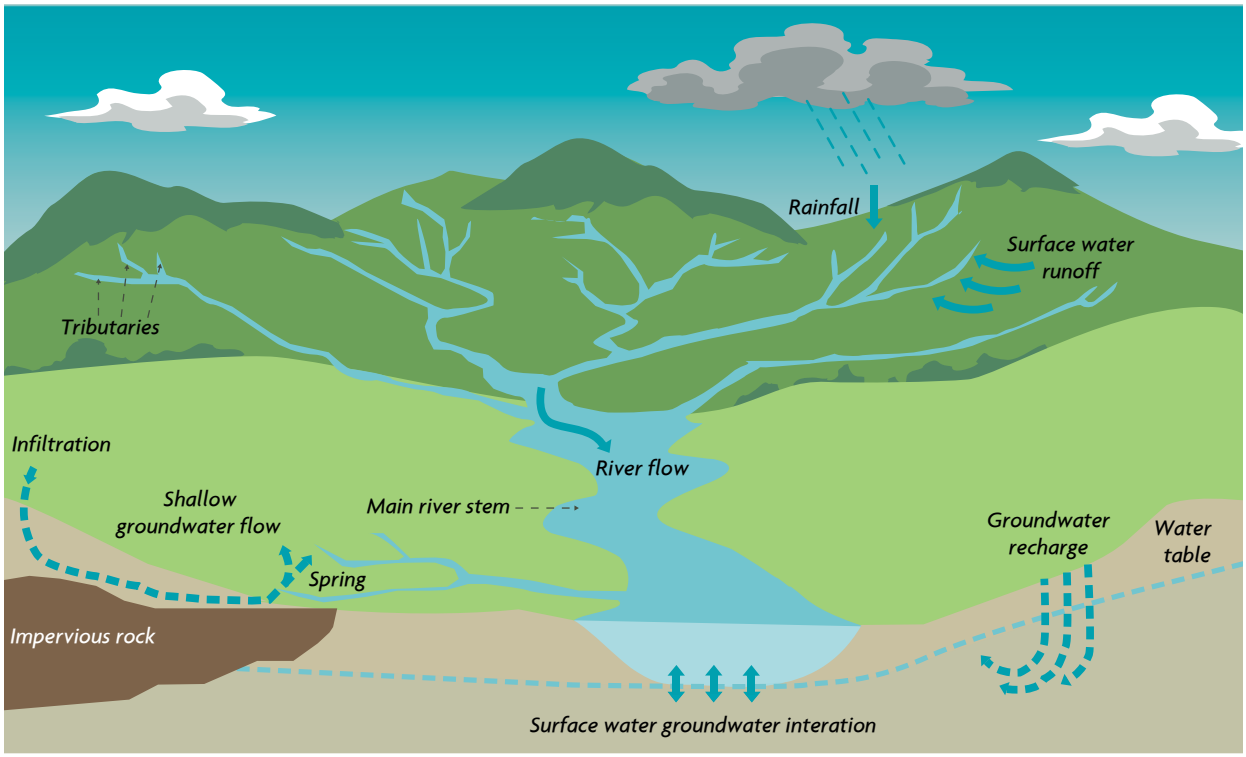
Catchments are connected by this flow of water, meaning what happens to water upstream or on-farm influences water quality downstream. Even temporary streams and channels have an effect on water quality downstream because they typically make up a large volume of water flowing over land.

Ground and surface water are connected

It is important to note that groundwater and surface water are also connected and may interact. This interaction is shown in the diagram below.

- Surface water can reach ground water when it filters through soils to recharge groundwater.
- Groundwater can reach surface water when solid rock layers prevent water infiltrating downwards. This creates shallow groundwater flows which can reach the surfaces as a spring. Groundwater can also reach surface water if the elevation of the groundwater adjacent to a surface water body is higher than the water level in the stream. The surface water body can then gain water from the groundwater system.

This means that nutrients in groundwater have the potential to enter surface water and vice versa.



Action

Be aware of the location of water bodies (e.g. streams, rivers, creeks, drains, ponds and wetlands) on your farm and where they flow. Identify this by:

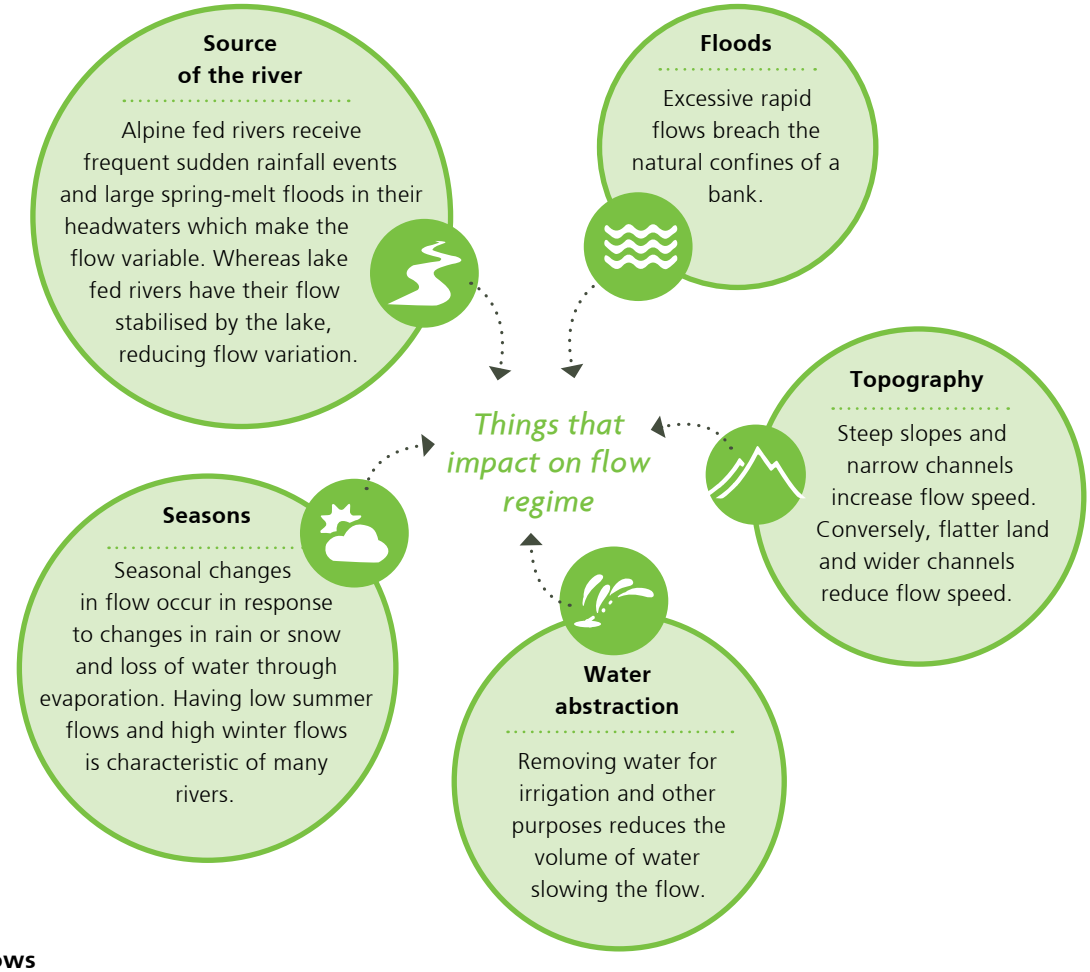
- Having a look around your farm during heavy wet weather events.
  - Where does the overland flow of rain water run?
  - What are the obstructions to this flow?
  - Are there any risk areas for sediment loss?
- Walk or drive along your waterway in the same direction as the flow, keeping in mind you may need to seek landowners permission for this if it flows onto other properties.
- Use online tools to follow the larger streams and rivers that flow from your farm:
  - Topographic maps **www.topomap.co.nz**
  - Google Maps **www.maps.google.co.nz**
  - Online maps on your regional council's website

Different types of water bodies react differently to excess nutrients, sediment and faecal bacteria

The amount of nutrients, sediment and faecal bacteria reaching a water body will depend on catchment features such as land use and practices, rainfall amounts and patterns, soil types and slope, and vegetation cover that intercept rainfall. Once in a water body the responses to nutrients (and sediment) differ between lakes and rivers.

Rivers

In a river, the flow determines the effect of excess nutrients on plant growth. The flow regime includes the volume of water, how fast the water is moving and when it flows. Rainfall is unevenly distributed across catchments and through seasons, so river flow is dynamic.



High flows

During high flows, like floods, river water is often fast moving. These flows flush out sediment and nuisance plant growth. The load may end up washed out to sea, deposited onto land or transferred into the next catchment.

The higher volume of water also means that concentrations of nutrients in the water are diluted reducing their potential environmental risk.

Low flows

During low flows, river water is often slow moving e.g. include dry summer periods or periods of demand for irrigation. The lower flow speed reduces the load of sediment and nutrient a river can carry.

Problems that can occur under low flow include sediment build up and nuisance plant growth because flows cannot flush the channel. The lower water volume also concentrates nutrients which poses greater environmental risk.

Lakes

Lakes are especially vulnerable because rivers deposit nutrient or sediment loads in them where they accumulate over time.

Deep lakes:

Sediment and P can settle on the lake bed indefinitely. Excess N and P can result in algal blooms. When algae die they sink to the bottom of the lake bottom and begin to decay. This releases nutrients back into the lake which are recycled and consume oxygen in the process. Low levels of oxygen in the water can cause stress to aquatic life.

Shallow lakes:

Shallow lakes are sensitive to excess nutrients and sediment because wind and waves tend to stir up sediment more readily. This reduces clarity and shades out high value plants on the lake bottom, therefore resulting in loss of aquatic habitat for main species and a decline in water quality.

What is the water quality like in my stream?

Action

Look at the streams on your farm.

- Is there excess plant growth in the stream?
  Remember plant cover can be good; it tends to be bad if it is clogging a stream bed and there is no exposed gravel or sand visible.
- Does it change colour after it rains?
- Is any effluent or sediment running into the water from land, bridges, races or culverts?
- Is any aquatic life visible?
- Do stock have access to the water?
- Is there any erosion or slumping of the river banks?

Review

Where can I seek further information?

- Ask your regional council catchment management officer for a summary of water quality and relevant actions for protection in your catchment.
- Ask your sustainable dairying advisor or an environmental representative from your milk company for industry resources, advice and programmes to help you farm sustainably.
- Contact DairyNZ who can provide useful resources and suggest other avenues for technical support on 0800 4 DairyNZ (0800 4 324 7969).

Where are the hotspots for nutrient losse

Stock-dung and urine

N, P, faecal bacteria and sediment

Pathway: Runoff, leaching and direct deposition.

Signs: Stock on paddocks during wet periods, ponding and overland flow, collections of dung in areas of a paddock prone to overland flow/flooding, ruts from vehicle movements, slips or slumps, extensive pugging.

Stand-off Areas

N, P and faecal bacteria

Pathway: Runoff or leaching if effluent is not effectively captured

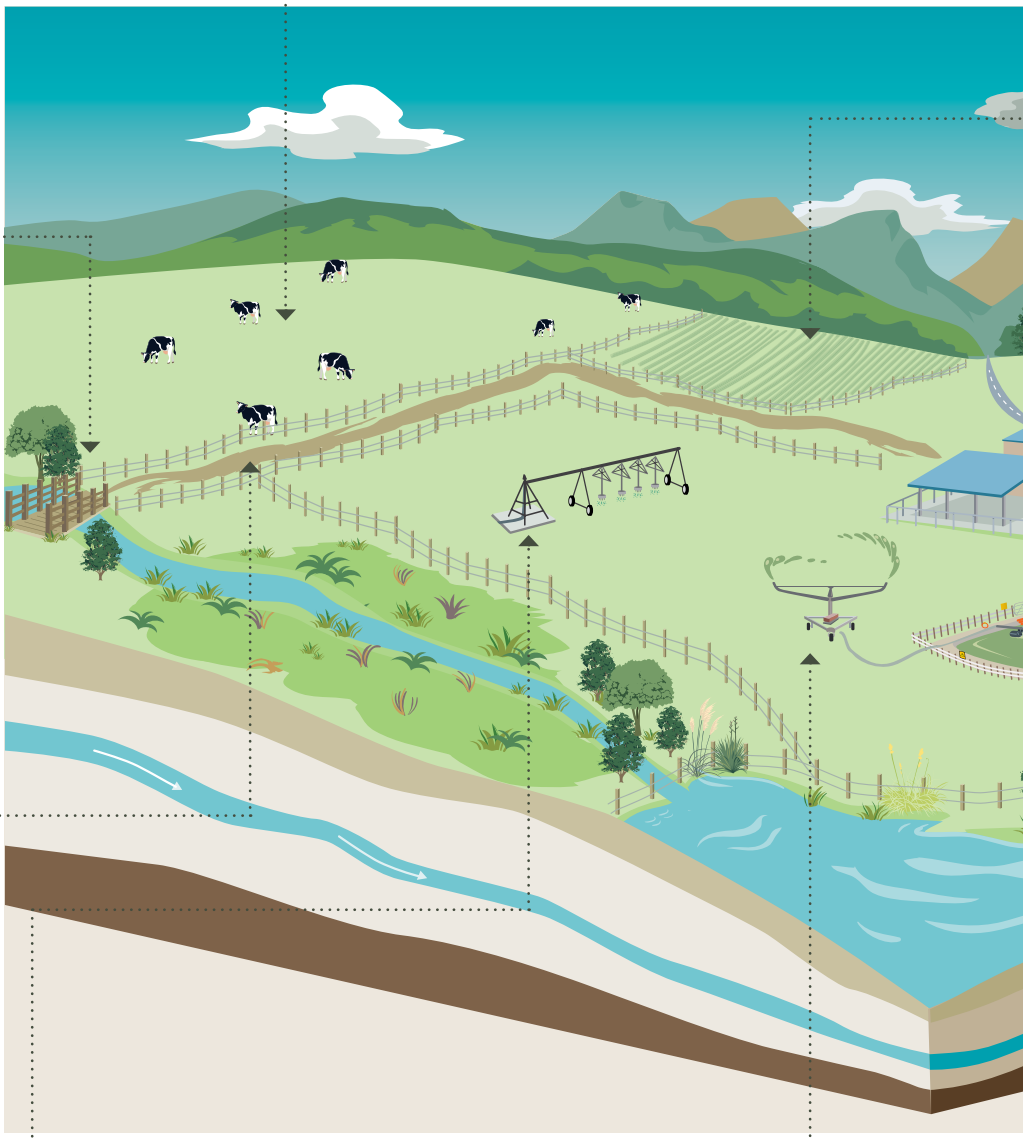
Signs: Effluent running off pad.

Bridges and culverts

N, P, faecal bacteria and sediment

Pathway: Runoff into water and direct deposition.

Signs: Effluent, or water containing effluent, running off to channels that lead to water or directly to water. Effluent accumulating in areas where cows congregate.



Races

N, P, faecal bacteria and sediment

Pathway: Runoff into water and direct deposition.

Signs: Races in bad repair, with potholes and boggy patches. Water channels scoured into the race, particularly on steep slopes. Effluent, or water containing effluent, running off to surface water. Effluent or other materials built up, poor drainage.

Irrigation water

Generally irrigation water is not a source of nutrient loss. Like rain, irrigation water decreases the available water holding capacity of soil which increases the risk of N leaching. Over saturation of soils can also lead to pooling and runoff.

Effluent irrigation

N, P and faecal bacteria

Pathway: Runoff or leaching. This can occur for several reasons, for example: if infrastructure is not well maintained, if effluent is applied at a rate or depth that is too high.

Signs: Burst pipes, blocked nozzles, pumps failing, irrigation over or close to water, ponding, dead worms at the surface, or grass browning after application.

es on a dairy farm?

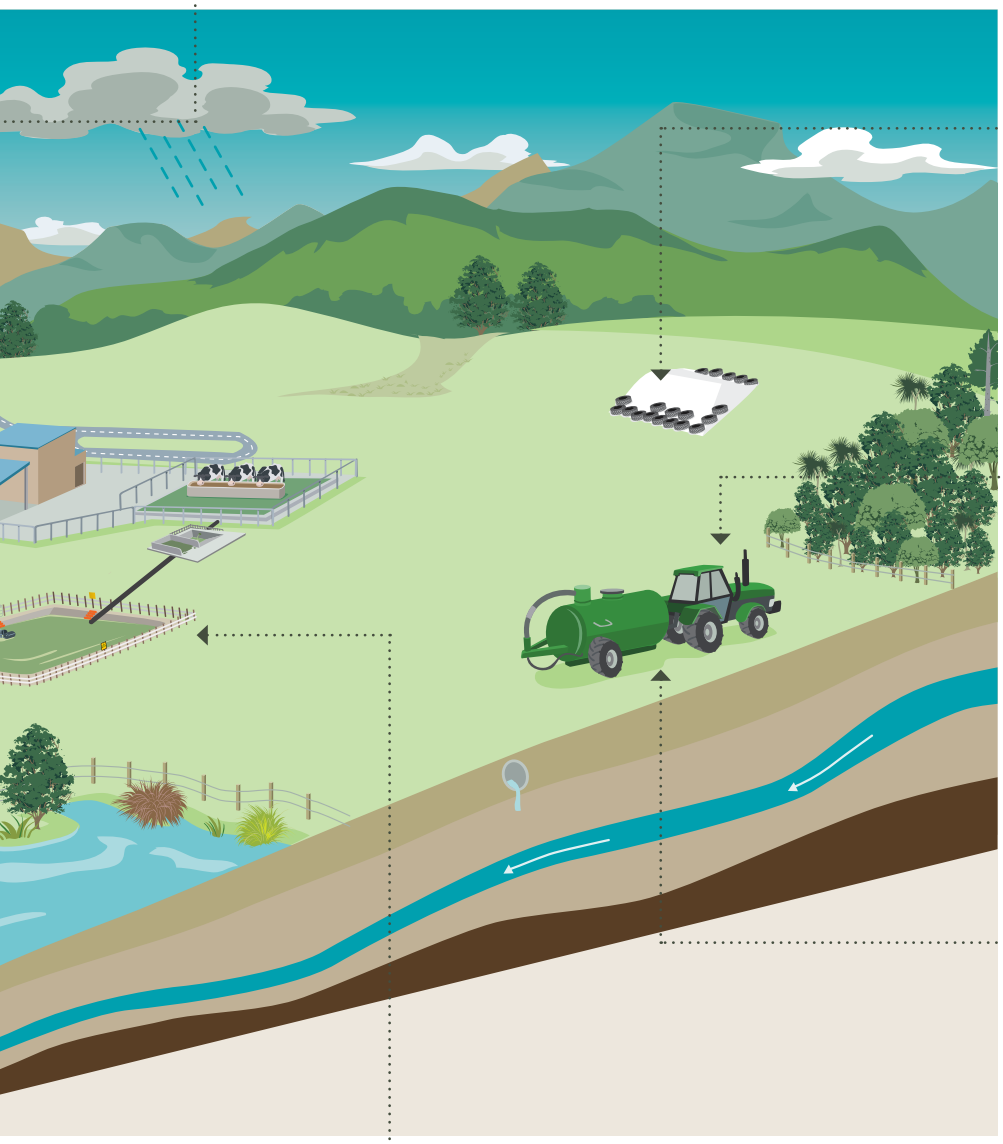
Crops

N, P, faecal bacteria and sediment, depending on if the crop is grazed or harvested.

Pathway: Runoff, leaching and erosion from stock, fertiliser applications, cultivation and harvesting activities.

Signs: Effluent or sediment running off into water during grazing of crops. Heavy rain washing soils off cultivated areas. Build-up of dung or disturbed soil in areas with the potential to runoff.

Note: Leaching is difficult to see



Supplemental feed storage

N and P

Pathway: Runoff from the stack or leaching below the stack.

Signs: Dark liquid leaking from stacks or bales.

Fertiliser storage

Depending on the fertiliser, could be N and/or P

Pathway: Runoff or leaching if fertiliser is exposed to elements.

Signs: Fertiliser getting wet, visible runoff from storage site.

Fertiliser application

Depending on the fertiliser, could be N and/or P

Pathway: Runoff or leaching if fertiliser applied in inappropriate amounts, locations, or times.

Signs: Applying fertiliser close to or in waterways, applying fertiliser when the soil already has adequate amounts, applying fertiliser to wet soils or very dry cracked soils.

Effluent ponds and related infrastructure

N, P and faecal bacteria

Pathway: Runoff or leaching.

Signs: Overflow of sump or ponds, pond level lowering without discharge indicates it may be leaking, vegetation on the surface which may cause blockages and system failures. Yards with cracked concrete.

Offal pits

N, P and bacteria

Pathway: Runoff if the pit is in a location where water can run in and out or leaching if the pit is located within the groundwater level or not adequately compacted.

Signs: Water in the bottom of the pit, water flowing in or out of the pit.

How do the natural features on a dairy

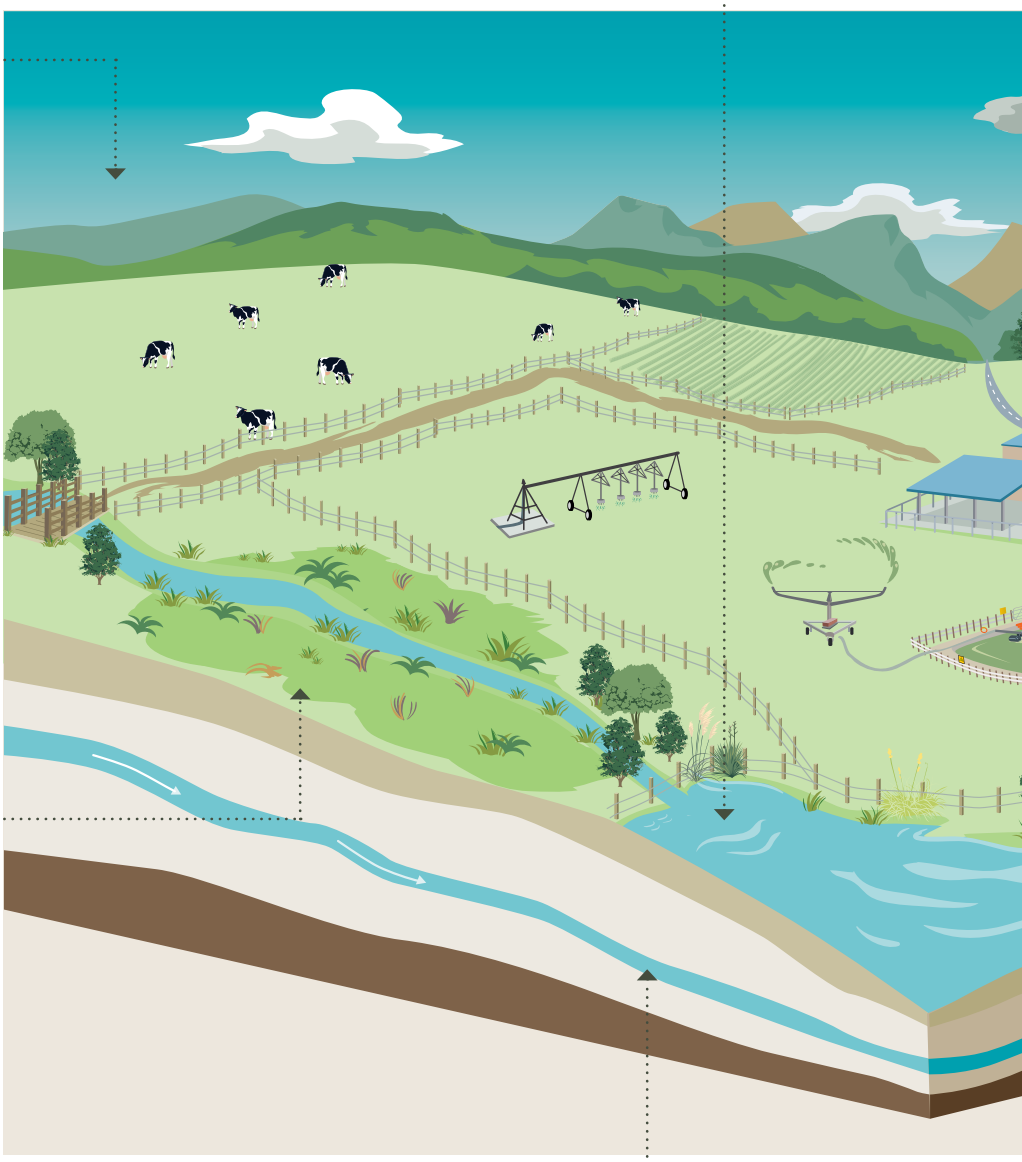
Steep areas

The nature of steep areas means they are more likely to have episodes of runoff to water, slips and slumps. This can be worsened by grazing stock on steep areas during high risk times and by inadequate planting for slope stabilisation.

The risk is that the soil or runoff lost from these areas will have P bound to it or N dissolved in it which could then be carried to waterways.

Surface water

Surface water on your farm includes rivers, streams, creeks, above ground drains, ponds, lakes, estuaries and wetlands. Also consider temporary waterways as they can channel runoff, and nutrients or sediment into main waterways during wet periods. Signs that you have excess nutrients entering your surface water include excessive plant growth in water bodies, rivers and streams changing colour after rain, effluent or sediment entering waterways from bridges or culverts, stream or bank erosion, stock access to waterways and stock grazing near waterways.



Wetland areas

Wetlands are permanently or intermittently wet areas, shallow water, and land water margins that support a natural ecosystem of plants and animals adapted to wetland conditions. They could be naturally occurring or constructed.

Wetlands are beneficial to your farm system. They enhance aesthetics and biodiversity, and can provide a habitat for wildlife and fish. They can be thought of as giant sponges, slowing the flow of water off land which can reduce flood peaks.

Wetland plants trap sediment and the wetland soils filter nutrients. A fully functional wetland can considerably reduce the N and P lost from your farm.

Groundwater

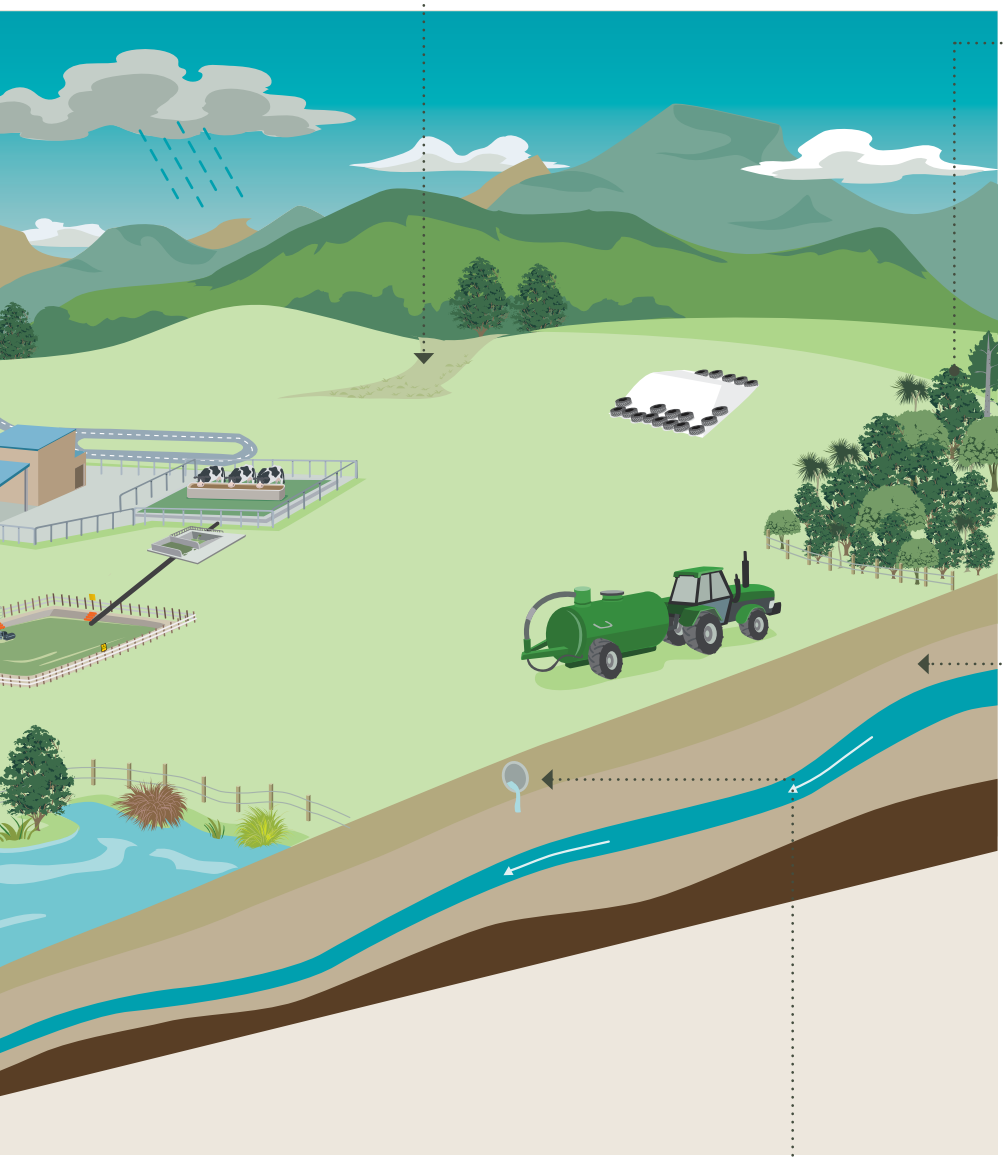
The groundwater level of your farm can be difficult to determine. However, it can be assumed that groundwater assumes similar channels to surface water and will appear in the overlying surface water catchment. There may be places on your farm where groundwater is close to the surface. The application of N, effluent or urine patches to these areas, particularly when the soil is wet, can increase the risk of N leaching to groundwater. It is very difficult to remove N from groundwater once it reaches it.

farm contribute to losses?

Gullies and other low or wet areas

These areas may be dry for long periods of the year. During high risk times water tends to wash over the higher surrounding land into these low areas bringing with it any dung, urine, fertiliser or effluent that is present. These channels often flow into farm drains, rivers or streams creating water quality problems.

During winter pugging by stock soil structure can be damaged making it less productive in the periods when they are dry.



Vegetated areas

Farms often have patches of native bush in gullies or on the top of steep hills. They have many aesthetic and biodiversity related benefits to the farm system.

Vegetated areas provide appropriate land management in high risk areas. They manage runoff and drainage and help to prevent erosion by holding soils together.

Soils

Soils are a very valuable, but limited resource. Damage or degradation through pugging, erosion and earthworks damages soil structure which in turn can affect drainage and potential losses of soils.

Soils hold nutrients (N dissolved in soil water and P bound to soil particles). Knowing the amount of nutrients in your soil is important as it will help you to work out which nutrients are limiting production (not enough or too much).

It is important to know what kind of soils you have and where they are located on your farm. They have a big impact on the loss of N through leaching and P through erosion.

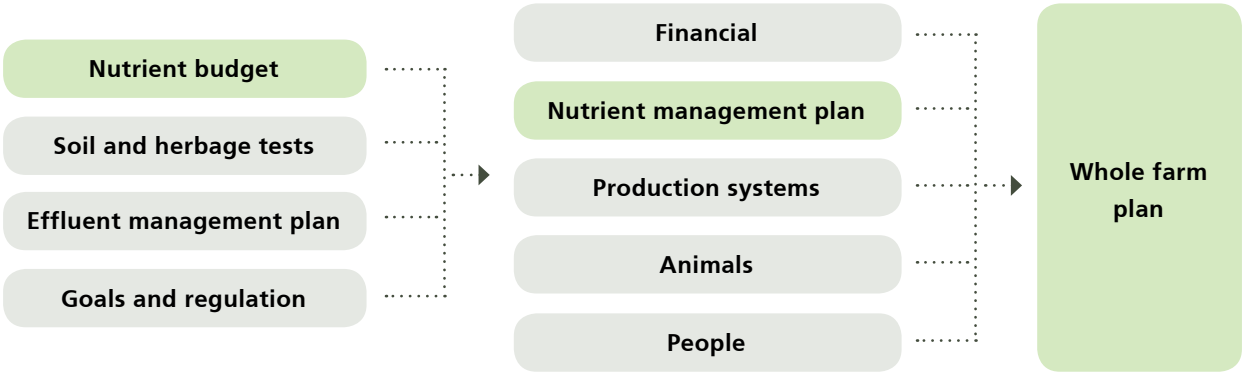
Subsurface drains

It is important to know the location of subsurface drains on your farm. Application of N, effluent or urine patches to soil above these drains during wet periods can increase the risk of nutrients leaching into the drains.

This can be quite visible after an effluent application if the drain discharges into surface water as the discharge runs brown.

Tools to understand and improve nutrient use on your farm

There are many tools that can help you understand nutrient use and losses from your farm system. These include nutrient budgets, nutrient management plans and whole farm plans.



Quick facts

- A nutrient budget indicates how nutrients are coming onto your farm and where they are going. It enables you to measure current and predicted nutrient use efficiency and losses.
- A nutrient management plan uses your nutrient budget to identify improvements to your current nutrient management regime that meet your on-farm productivity and environmental goals and objectives. It takes into account regional requirements (N loading rate on effluent areas) and industry accepted best management (optimal soil fertility levels). A nutrient management plan can help you address on-going issues associated with nutrient management.
- A whole farm plan considers the whole farm business including financial, people and production systems, along with animals and natural resource management. It also contains the goals and objectives for the dairy farm business.

What are nutrient budgets?

A nutrient budget is a tool to help you determine fertiliser requirements, estimate how efficiently a farm is converting nutrient inputs (such as fertiliser, imported feed) into outputs (such as milk and meat) and to indicate changes within the farm system.

Essentially, a nutrient budget adds up all the nutrient inputs and subtracts all the estimated outputs. It does this for the major nutrients: nitrogen (N), phosphorus (P), potassium (K), sulphur (S), calcium (Ca), magnesium (Mg) and sodium (Na).

How nutrient budgets are developed

Having a nutrient budget is a condition for supply in many dairy companies. In some regions, it is also a regional council requirement for resource consent.

Nutrient budgets are typically developed by fertiliser representatives or farm consultants using the OVERSEER® nutrient budget model. There are three key steps: information, analysis and action.

Information

Gather information on:

- Farm physical properties
- Farm system
- Soil testing
- Foliage testing
- Animal testing

Analysis

- Nutrient management advisor enters data into the Overseer model
- Scenarios are tested

Action

- Fertiliser recommendations
- Changes required identified
- Nutrient management plan developed to improve performance

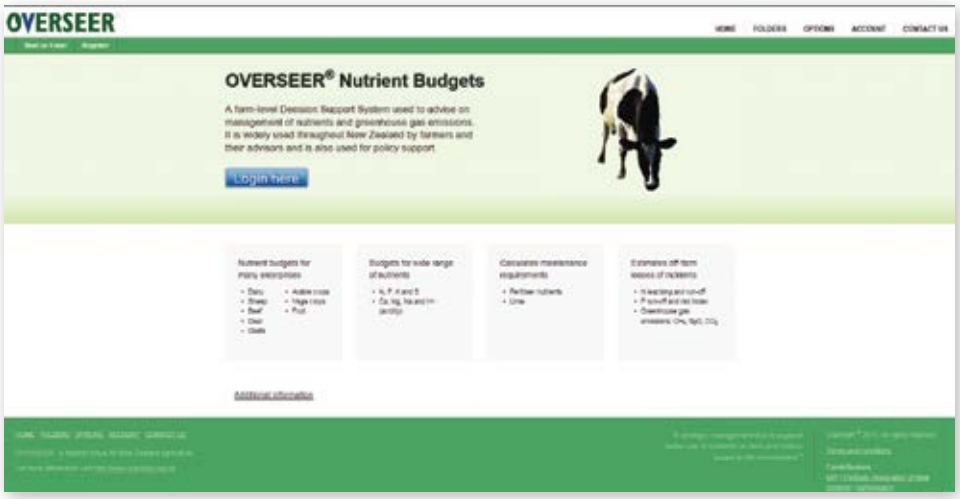
A nutrient budget is similar to an annual financial budget in that it:

- lists revenue/income from different sources (nutrient inputs)
- subtracts expenses (nutrient outputs)
- has a surplus or deficit.

And like a financial budget, it will not tell you how to run your business. It is only a tool to help make decisions. If your business is running at a loss, a financial budget alone will not solve the problem. You need to act on the information it provides. This applies to a nutrient budget as well.

The Overseer® Nutrient Budget Model

Overseer is a computer model tool which supports on-farm decision making around nutrient management. Overseer estimates nutrient flows through the animal, pasture, crop and soil. Nutrient budgets for eight nutrients including N and P are calculated.



Overseer was developed in the early 1990s and has since undergone repeated revisions to improve the model as new science and knowledge is produced. Overseer was developed in New Zealand for New Zealand farming systems. It has been calibrated against New Zealand research farms. As a result it is validated for use on the major soil types to predict long-term annual average nutrient losses to a high degree of accuracy.

Getting the best from Overseer

Like all models, Overseer does have limitations and there are a number of things that you should consider when using it.

1. Overseer is sensitive to the accuracy of the input information – using poor or unreliable data will give a poor or less accurate picture of nutrient use and losses. Make sure information about soil types, block set-up, production levels and nutrient inputs are right.
2. Overseer is a long-term annual average model – it is not designed to calculate nutrient flows through a farm system on a daily basis or in a specific year. Rather, it considers the effects of nutrient use over a long-term period.
3. Overseer also assumes the farm system is in balance – that productivity (stock, milk production) is achievable and matched by realistic feed inputs.
4. The model assumes that any on-farm management practices such as effluent applications, fertiliser use and irrigation use, follow best practice. This is very important; it means that any changes you make on farm to bring your farm into line with accepted best practice, e.g. fence waterways or improve effluent application, will not reduce your N leaching predicted by Overseer.

Frequently asked questions about Overseer

1. What happens when a new version comes out?

When a new version of Overseer is released, nutrient management advisors are notified. The version of Overseer that they are using will be updated. The new version will be used for the majority of nutrient budgets nationwide from that point onwards.

2. Why are my numbers different between different Overseer versions?

Overseer is a continually evolving program. This means that as better knowledge is developed and improvements made, outputs can be different from previous versions.

There has been a large change in the scientific understanding of N leaching and this has resulted in differences between version 5.4 and version 6.1 which was released in August 2013.

If you have any further questions about this you can visit **www.overseer.org.nz** and view the release notes which will summarise the main changes for new versions of Overseer.

3. What is the Dairy Industry Audited Nitrogen Protocol?

The Dairy Industry Audited Nitrogen Protocol for Overseer is a consistent set of guidelines designed for nutrient management advisors. It ensures that nutrient budgets are generated accurately and consistently and that they can be compared between advisors and farms anywhere in New Zealand. The protocol has been adopted by the major fertiliser companies and Fonterra. Other milk companies are likely to adopt it as well. Your next nutrient budget should be calculated using the Dairy Industry Audited Nitrogen Protocol.

The protocol may have some impacts on Overseer budgets but ensures that certain factors which have an overly large influence over the nitrate leaching values in Overseer are better accounted for.

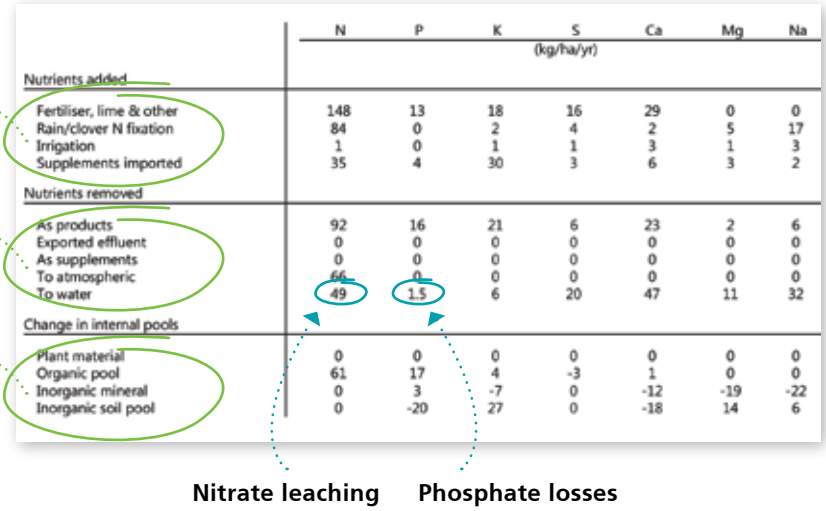
4. What do my numbers mean?

If your nutrient budget has been developed using the Overseer model then it should look similar to the picture below:

Nutrient inputs: These are the sources of nutrients onto your farm e.g. fertiliser, effluent, clover, imported feed supplements.

Nutrient outputs: Where nutrients are removed from your farm e.g. in milk and meat, as feed, as a gas, or lost to water.

Nutrients kept on the farm in soil and plants.



	N	P	K	S	Ca	Mg	Na
	(kg/ha/yr)						
Nutrients added							
Fertiliser, lime & other	148	13	18	16	29	0	0
Rain/clover N fixation	84	0	2	4	2	5	17
Irrigation	1	0	1	1	3	1	3
Supplements imported	35	4	30	3	6	3	2
Nutrients removed							
As products	92	16	21	6	23	2	6
Exported effluent	0	0	0	0	0	0	0
As supplements	0	0	0	0	0	0	0
To atmospheric	66	0	0	0	0	0	0
To water	49	1.5	6	20	47	11	32
Change in internal pools							
Plant material	0	0	0	0	0	0	0
Organic pool	61	17	4	-3	1	0	0
Inorganic mineral	0	3	-7	0	-12	-19	-22
Inorganic soil pool	0	-20	27	0	-18	14	6

Nitrate leaching **Phosphate losses**

The numbers in the blue circles of most interest when talking about environmental impacts: N removed (or lost) to water, P removed (or lost) to water.

- N removed refers to nitrates that are leached below the root zone of plants, and may be lost to groundwater as well as some overland flow.
- P removed refers to P losses from overland flow to water bodies.

5. How do I calculate my N surplus?

N surplus is the difference between N inputs (atmospheric, fertiliser, clover fixation, supplementary feed) and N outputs (milk, meat, exported feed). It can be calculated from your nutrient budget as shown below:

N inputs

N outputs in product

N surplus

	N	P	K	S	Ca	Mg	Na
	(kg/ha/yr)						
Nutrients added							
Fertiliser, lime & other	148	13	18	16	29	0	0
Rain/clover N fixation	84	0	2	4	2	5	17
Irrigation	1	0	1	1	3	1	3
Supplements imported	35	4	30	3	6	3	2
Nutrients removed							
As products	92	16	21	6	23	2	6
Exported effluent	0	0	0	0	0	0	0
As supplements	0	0	0	0	0	0	0
To atmospheric	66	0	0	0	0	0	0
To water	49	1.5	6	20	47	11	32
Change in internal pools							
Plant material	0	0	0	0	0	0	0
Organic pool	61	17	4	-3	1	0	0
Inorganic mineral	0	3	-7	0	-12	-19	-22
Inorganic soil pool	0	-20	27	0	-18	14	6

In this example:

N surplus = N inputs-N outputs in product
N surplus = (148 + 84 + 1 + 35) - (92 + 0 + 0)
N surplus = 176 kgN/ha/yr

6. What is nitrogen conversion efficiency?

N conversion efficiency (NCE) describes what proportion of the N input has been converted to product N (e.g. milk, meat and feed). This should give you an indication of how efficiently you convert N into product on your farm. For more information about NCE refer to page 37 in this booklet: "What should you focus on to improve nutrient use on your farm?"

$$\textit{Nitrogen conversion efficiency} = 100 \times \frac{\textit{N output in product}}{\textit{Sum of N inputs}}$$

In this example:

$$NCE = 100 \times \frac{(92 + 0 + 0)}{(148 + 84 + 1 + 35)} = 34\%$$

Your NCE value is also found in your Overseer nutrient budget on the nitrogen overview summary:

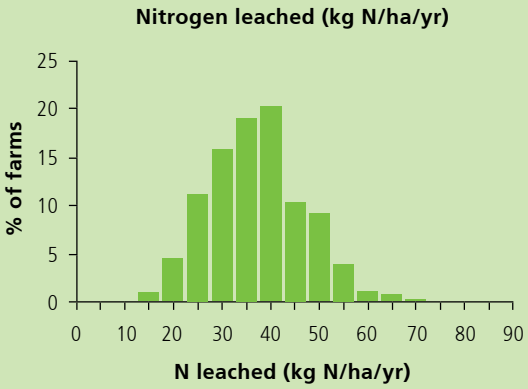
	Units	Benchmark farm	Current farm
Inputs (farm average)			
Clover N	kg N/ha/yr		82
Fertiliser N	kg N/ha/yr		148
Other N added	kg N/ha/yr		38
Indices			
Average N loss to water	kg N/ha/yr	24-42	49
includes N lost as effluent	kg N/ha/yr		0
N_2O emissions	kg N/ha/yr		7.4
For pastoral area of farm:			
Farm N surplus	kg N/ha/yr	123-191	175
N conversion efficiency	%	27-35	34

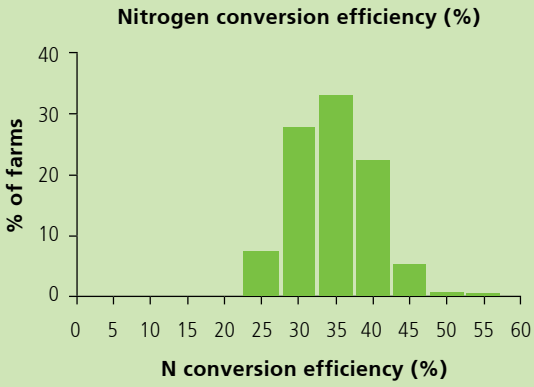
Nitrogen conversion efficiency

Action

A quick way to work out how well you are managing nutrients is to compare yourself to your peers. As part of the Sustainable Dairying: Water Accord 2013 dairy companies are committed to providing N loss and N conversion efficiency performance information and performance benchmarks back to dairy farmers.

One way this information could be presented is in graphs like the ones shown below. They enable you to check how your farm compares to others in your region.





Review

- How do the numbers from your nutrient budget compare to those on the graph for your region?
- Ask questions of your fertiliser rep, sustainable dairying advisor or area manager from your milk company to find out more. E.g. What accounts for the differences in your results? Is it soil types, climate or management practices?

What are nutrient management plans?

A nutrient management plan (NMP) is a written document that describes how your nutrients can be best managed. In your NMP your current nutrient management regime is identified, your goals for the future are outlined and clear pathways are set out for you to achieve the goals. If you are having issues on farm, perhaps regarding compliance, a NMP can also help you to address these and create a working plan.

How are nutrient management plans developed?

NMPs are living documents which are developed to give you flexibility to respond to external factors that can be outside your control (e.g. climatic events, market price changes). This is shown in the next diagram.

A good nutrient management plan will include:

- physical details of your farm
- your farm goals and nutrient based goals
- any regulatory conditions (e.g. regional council rules) or industry requirements (e.g. Sustainable Dairying: Water Accord) that need to be complied with
- recent soil, plant and animal tissue testing, with particular reference to longer term trends from regular monitoring programmes
- a current nutrient budget
- recommendations on how to meet specific nutrient goals.

Who can create my nutrient budget or nutrient management plan?

A good understanding of farm management and nutrient management systems is required to ensure that accurate data is collected and used to develop nutrient budgets, determine fertiliser requirements and identify strategies to improve nutrient use.

For this reason, it is important that Overseer is used with the support of a qualified nutrient management advisor, such as a fertiliser representative or farm consultant.

A nutrient management plan should also be developed by an advisor who is trained in nutrient budgeting and has knowledge and skills around soil fertility, fertiliser use and farm system management.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What should you focus on to improve nutrient use on your farm?

Nutrient loss can be influenced by physical factors, such as soil types and climate, as well as farm management factors, including fertiliser, pasture and imported feed use.

Because of the influence of the physical and farm management factors it is important to discuss any nutrient figures you receive with your nutrient management advisor, particularly if they are different from the averages in your region.

Focus areas to improve nitrogen loss:

1. Minimise the number of urinations per unit area especially at the high risk times through:
   - reduced stocking rates
   - winter cows off in less sensitive catchments
   - incorporate standoff pads and herd shelters.
2. Use low N feeds at high risk times, this will reduce the nitrate concentration in the urine.
3. Develop wetlands and riparian buffers to uptake and convert nitrate N and prevent it running off to waterways.
4. Increase the size of the effluent block so that the rate of N application is appropriate for plant growth.
5. Use N fertiliser as required but only when the pasture is growing and can utilise the applied N. Apply low rates > 25-30 kg N/ha in any given application.

Focus areas to improve phosphorus loss:

1. Minimise the runoff of surface water and soil into waterways though:
   - targeted planting of critical areas such as springs or steep unproductive slopes
   - management of wet soils
   - management of winter forage crops
   - optimising Olsen P status.
2. Stopping direct deposition of P (for example fertiliser and effluent) into waterways through:
   - stock exclusion from waterways
   - efficient effluent systems and management
   - strategic phosphate fertiliser applications.

Keep in mind:

Changing an aspect of your nutrient management can have a range of different flow on effects and needs to be considered in the context of your farm system, your business goals and any regulatory requirements.

If it is determined that the change you would need to make to reach regulatory requirements is expensive or would have major impacts on your farm system, then DairyNZ recommends you consult with experts. These experts will vary depending on what your need is but could include: someone with experience in the specific area concerned, a farm systems expert, a nutrient management expert, your bank manager or resource consent experts.

Key Messages: Managing for improved nitrogen conversion efficiency and nitrogen leaching on dairy farms

The industry is committed to responsible milk growth while contributing to maintaining and improving water quality to meet community agreed freshwater objectives. On all farms this means more efficient use of the current nitrogen (N) input for milk production. On some farms N leaching will need to be reduced to contribute to catchment limits.

The key is for farmers to convert N inputs into product efficiently and profitably, while ensuring that N leaching from their farm is reasonable for their soil and climate.

Nitrogen conversion efficiency, N leaching and N surplus, are measures that help farmers understand how well nutrients are being used on their farms and allow them to make improvements.

Nitrogen conversion efficiency (NCE) describes the proportion of nitrogen going into a farm (N inputs) that is converted to nitrogen in saleable product (N outputs). NCE equals N output divided by N input and is expressed as a percentage[1].

N surplus is the nitrogen that remains after the conversion of nitrogen inputs to saleable product such as milk, meat, and supplements sold off the farm, (N inputs - N outputs = N surplus) . The N surplus is mostly what is excreted by animals in urine and dung.

N leaching[2] results from the N surplus. The amount of N leaching is influenced by both farm management and non-management factors such as the volume of rain and some soil characteristics.

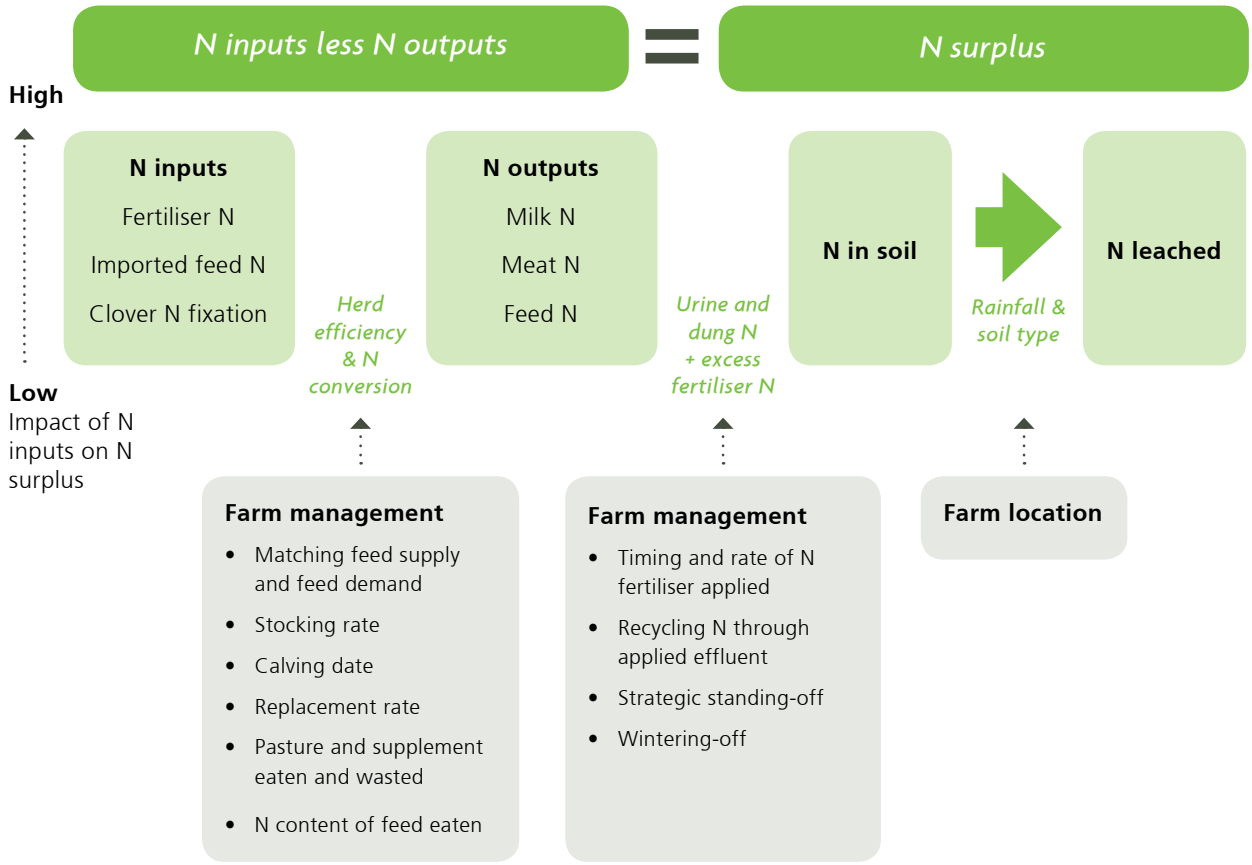
Every dairy farm has unique characteristics that will influence its N leaching loss risk.

These can be physical factors such as soil types and climate, or farm management factors such as stocking rate, nitrogen fertiliser use, pasture and imported feed use, and pasture types. The diagram overleaf illustrates where management and physical factors can make a difference.

[1] $\text{NCE} = \frac{\text{N outputs in saleable products}}{\text{Sum of N inputs}} \times 100\%$

[2] N is leached from soil in the nitrate form so is also called nitrate leaching

Relationship between nitrogen conversion efficiency, nitrogen surplus and nitrogen leaching



Improving nitrogen conversion efficiency

A number of factors can impact on why nitrogen conversion efficiency is low and contributing to higher than desired nitrogen (N) leaching. These include:

- low N output in milk relative to N input
- high N fertiliser use per ha for the kg milksolids (MS) produced per ha
- a high proportion of N fertiliser is applied in months with low pasture growth and high rainfall
- low feed conversion into milk by the herd. That is, high feed N input but low MS/ha
- N from the effluent system is used poorly to replace fertiliser N and to grow feed on the farm.

Low cost solutions include:

Better fertiliser management:

- match fertiliser N inputs to feed budgets and pasture growth rate
- avoid applying when pasture growth is low (too cold, soil temp. less than 7°C), or too wet
- apply fertiliser N at no more than 25-30 kg N/ha per application
- use non-N alternatives to boost pasture production (e.g. gibberellic acid).

Improved feed conversion

Common reasons for low feed conversion are:

1. A high proportion of feed being used for maintenance of cows – either too many cows or too few lactation days relative to days dry.
2. A high proportion of feeding to dry cows relative to milking cows (short lactations or too many replacements).

Improving feed allocation means that more of the right feed is fed in the right amounts, at the correct time, to the most efficient cows. This could involve:

- reviewing stocking rates, and calving (and drying off) dates
- reducing the time that cows are on the farm but not producing milk going into the vat, e.g. cows being treated for mastitis, late calving cows or cows dried off early.

Better effluent management

Increasing the amount of effluent N used and reducing nitrogen fertiliser inputs by a comparable amount makes good sense where this can be done cost effectively and within regulations. To ensure effluent nitrogen is being used effectively:

- complete a separate nutrient budget for the effluent block
- ensure the block used for effluent applications is the optimum size
- use the effluent block for forage crop production
- match effluent applications to soil moisture deficit levels.

Time off pasture to manage recycling of dung and urine

Herds spending time on stand-off pads and herd shelters reduce urination events on pasture and provide an opportunity to capture and recycle dung and urine to pasture at times more suitable for pasture growth.

If suitable, these types of strategies should add to good management practice in other areas of the business. They are often capital intensive and may affect business viability if not carefully integrated into the farm system.

Relative significance of factors that influence nitrogen conversion efficiency

The following table below outlines the expected impact of a number of factors on nitrogen conversion efficiency (NCE). It is not always possible to accurately predict the response to changing one of these factors as there are a number of interconnected parts. However research and various farm reviews have shown that in general these are the most likely responses.

It is also important to remember that high milksolids (MS) per hectare or MS per cow, does not always mean more profit, and before targeting these to improve NCE, impacts on profitability for the whole farm system should be considered. Likewise high producing farm systems with high N inputs and high N outputs can have high NCE but retain high values for N leaching.

It is therefore extremely critical that any farm changes are considered across the whole farm system and evaluated for impacts on profit as well as impacts on NCE and N leaching.

Relative significance of factors that influence nitrogen conversion efficiency (NCE%)

Ranking	Factors	Impact	Likely Change	Application on farms
1	Annual N fertiliser rate (kg/ha)	High	Increased N fertiliser usually reduces NCE	On many farms increased N fertiliser is likely to increase N leaching.
2	MS/ha or MS/ cow	Medium	Increased MS/ha or MS/cow usually increases NCE	More MS is also likely to increase N leaching/ ha. Where catchment limits are fully allocated, opportunities to increase MS/ha and NCE% will be limited
3	Cows/ha	Medium	Increased cows/ha slightly increases NCE	Where farms are still developing and increasing pasture growth, more cows accompanied by more MS/cow should improve NCE%. N leaching may also increase. Where catchment limits are already fully allocated opportunities to increase NCE% will be limited.
4	Wintering off	Low	More wintering off has slight beneficial effects on NCE	This applies to the milking platform, and may not reduce the total N leached if the area where the cows are wintered is counted.
5	Nitrogen (N) content in Feed	Low	Lower feed N in imported feed can improve NCE	Requires a significant substitution of a cheaper high protein feed, (pasture) with a more expensive, lower protein feed such as maize silage.

Farm location will modify the required actions

1. For all farmers the focus should be on improving NCE without excessive N leaching while maintaining and/or enhancing profit. This can be achieved by optimising the efficiency of the farmers' chosen system.
2. Where catchment limits are in place the focus will be on meeting the farm's N leaching limit, and being profitable within that limit. The suggested first step is reducing N surplus; then mitigating the amount of loss from N surplus (e.g. standoff etc.).
3. In some districts there is likely to be a requirement for farmers to commit to reduced N leaching over time.

Summary

- Nitrogen (N) that is surplus to pasture requirements has the potential to be lost to the environment (e.g. leached below the plant's root zone).
- Estimates of the N surplus and N leaching loss for your farm are modelled and monitored using the Overseer model.
- Overseer also quantifies nitrogen inputs and outputs for your farm, and determines how well N is being used to grow grass and produce milk, ie the N conversion efficiency.
- Keep records of quantities and timing of your N inputs, (fertiliser and imported feed) so that you can accurately monitor progress in Overseer.
- If N conversion efficiency is low it will contribute to higher than desired N leaching.
- Discuss your estimated N leaching and your N input, N conversion and N output figures with your nutrient management advisor (e.g. fertiliser representative or farm consultant).
- The impact on profitability of any changes to reduce N leaching needs to be considered. Farm system modelling programmes such as Farmax, Udder and GSL can help in assessing impacts.

For more information

DairyNZ website

If you would like more information on general nutrient management, DairyNZ have a number of additional resources on our website **www.dairynz.co.nz.** Resources include:

- Reducing nitrogen loss booklet.
- Regional Riparian Management Guides and Land Management Guides.
- Waterway Technical notes.
- Farmfacts
    - sustainable dairying land and water management
    - effluent management
    - fertiliser and nutrient management
- Strategy for Sustainable Dairy Farming 2013-2020
- Sustainable Dairying: Water Accord (supersedes the Clean Streams Accord)

You can also access these via the Farmer Information Service. Phone: 0800 4 DairyNZ (0800 4 324 7969) or email info@dairynz.co.nz.

New Zealand Institute of Primary Industry Management (NZIPIM)

The NZIPIM is a professional association for people who manage primary industry resources and/or provide professional services to the primary industry sector. They have a list of NZIMIP registered consultants on their website.

Nutrient management advisors

Your trained nutrient management advisor i.e. a fertiliser representative or a farm consultant, will also be able to provide you with advice and information about measures and actions you can take to improve your farm's nutrient use efficiency.

Fertiliser association website

A range of information and resources are available on their website **www.fertiliser.org.nz**

- Code of Practise for nutrient management which includes further information on nutrient management plans
- Frequently asked questions (FAQs) such as:
    - how do I know if my fertiliser adviser is accredited?
    - nutrient management
    - how does fertiliser impact on water quality?

Milk companies

Ask your Fonterra Sustainable Dairying Advisor or an environmental representative from your milk company for more information on nutrient management and industry requirements.

Ministry for the Environment website

The central government website **www.mfe.govt.nz** has resources and links to national environmental policies including:

- National Policy Statement for Freshwater

Regional councils

Talk to your regional council to get more clarification around the current rules and requirements.

Area/region	Website	Phone number
Northland	www.nrc.govt.nz	0800 002 004
Auckland	www.aucklandcouncil.govt.nz	(09) 301 0101
Waikato	www.waikatoregion.govt.nz	0800 800 401
Bay of Plenty	www.boprc.govt.nz	0800 884 880
Gisborne	www.gdc.govt.nz	0800 653 800
Hawke's Bay	www.hbrc.govt.nz	0800 108 838
Taranaki	www.trc.govt.nz	06 765 7127
Manawatu	www.horizons.govt.nz	0508 800 800
Wellington	www.gw.govt.nz	0800 496 734
Tasman	www.tasman.govt.nz	03 543 8400
Nelson	www.nelsoncitycouncil.co.nz	03 546 0200
Marlborough	www.marlborough.govt.nz	03 520 7400
West Coast	www.wcrc.govt.nz	0508 800 118
Canterbury	www.ecan.govt.nz	0800 324 636
Otago	www.orc.govt.nz	0800 474 082
Southland	www.es.govt.nz	0800 76 88 45

dairynz.co.nz