

Chemical/Physical Factors: Factsheets

These fact sheets can be used to provide more information about the parameters you are investigating. These parameters may have been:

- above or below the 'Catchment Clue' values
- identified in the field as a potential limiting factor
- outside the accepted optimum range¹.



¹ A comprehensive list of recommended values for each of the parameters is at the end of each of the fact sheets.

Temperature

Measuring water temperature is very simple and is a very important factor in water quality. However, the significance of temperature on water quality is not straightforward because water temperature influences many different properties of water.

Several things determine the rise and fall of water temperature in a stream but the most important are weather and the season. Temperature variation along the length of a stream can be extreme in hotter months as it is affected by factors such as water depth, shading and flows from other sources. Daily temperature changes greater than 10°C have been recorded in some streams in summer.

Many of the physical, chemical and biological characteristics of streams are directly affected by temperature.

Importance

- **Water temperature influences the amount of oxygen that can be dissolved.**

Warmer water cannot hold as much oxygen as cooler water. Organic matter in a water body will compound the problem as microbes use up more dissolved oxygen while decaying.

Increases in water temperature will increase the metabolic rate of organisms in the water. Increased metabolism increases the oxygen demand of fish, aquatic insects and bacteria.

- **Temperature influences the rate of photosynthesis by algae and larger water plants.**

Warmer temperatures enable these plants to grow vigorously. Warm waters tend to be more susceptible to blooms.

- **Temperature influences the sensitivity of organisms to toxic wastes, parasites and diseases.**

Warmer temperatures stress most aquatic organisms and they become more vulnerable to other stresses. Fish are particularly susceptible to rapid temperature changes and can suffer undetectable internal damage.

Some species have different temperature needs at different stages of life. Generally fish larvae tolerate a narrower range of temperature than adult fish.

- **Temperature can control the structure of aquatic communities.**

If the overall temperature of a water body changes, so does the number and variety of organisms in the community. Stonefly numbers drop markedly as soon as maximum water temperatures exceed 19°C and temperatures which stay between 21°C and 24°C are lethal to many sensitive aquatic invertebrates. Different algal groups also flourish at different temperatures. For example, diatoms dominate at 20°C - 25°C, green algae dominate at 30° - 35°C, and cyanobacteria dominate above 35°C.

A short period of high temperatures each year can make the stream unsuitable for sensitive organisms even though the temperature during the rest of the year is tolerable.

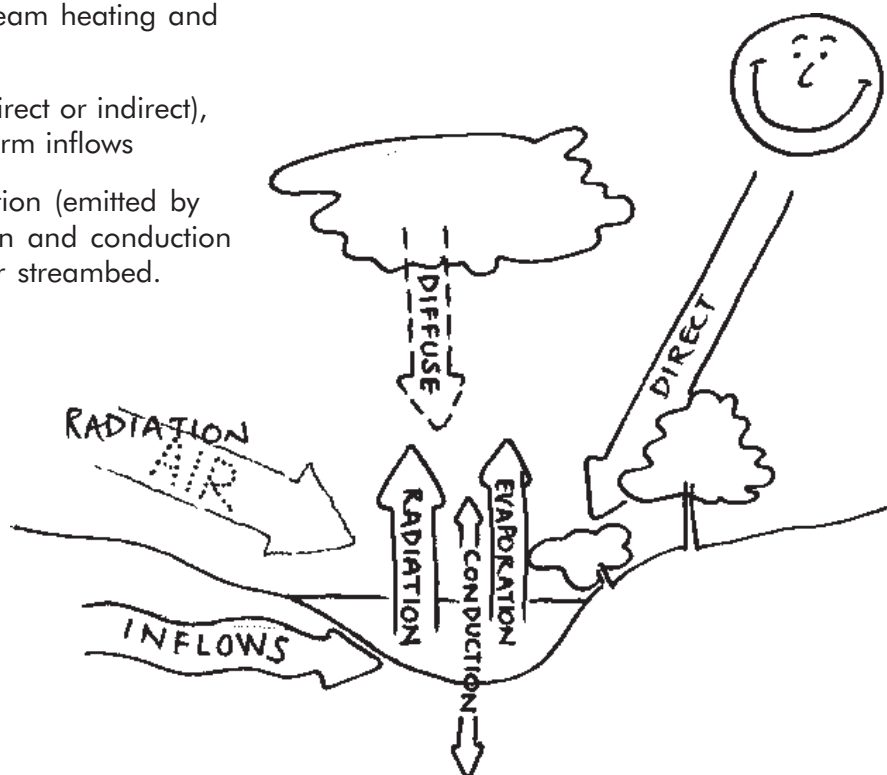
Other Sources Of Temperature Variation

Heating and/or cooling often causes environmental damage over time. Many of these problems are caused by humans:

- Warm runoff from urban surfaces such as streets, footpaths, car parks and rooftops can substantially affect the temperature of the receiving water.
- Clearing riparian vegetation allows the sun to shine directly into the water. Heating is more noticeable in smaller waterways.
- Sediment and other suspended material absorb heat from the sun. Sediments can also decrease the depth of channels, increasing the surface area and contributing further to the problem.
- The shading provided by banks is usually removed by channel works (straightening, widening etc.) on farms and in urban areas.
- Dams that collect water to form wide ponds increase the surface area and storage time. Both contribute to increased water temperature. Deep reservoirs have the opposite effect and discharges may be considerably cooler than the natural temperature. The temperature of cooled water could be lower than the tolerance or lethal limit of some aquatic organisms.

Principal causes of stream heating and cooling:

- Inputs from sun (direct or indirect), air (warm) and warm inflows
- Losses from radiation (emitted by water), evaporation and conduction (to cool air and/or streambed).



Controlling Temperature Variation

- Restoring shade on banks will reduce maximum water temperatures in streams. Fencing out stock and encouraging grass, fern and sedges to grow may provide enough shading achieved in small, narrow (1-2m wide) pasture streams. In wide streams (greater than 5m) tall trees are needed. Tree spacing and density will affect how much shade is provided by riparian vegetation.

Note: Although it is possible to restore shade at a site, the temperature benefits may not be experienced for some distance downstream, after the water has cooled.

- Avoid activities that decrease water clarity (see Controlling Loss of Water Clarity on page 6). Heavy rain, followed by surface runoff or erosion, and increased growth rates of algae contribute to peak turbidity in summer.

- Reduce irrigation use during periods of low flow. Temperatures increase as a water body becomes shallower.
- Water running off from irrigation may be heated as it passes over hot soil. Irrigation during cooler periods of the day or at night will reduce this effect and minimise water loss from evaporation.
- The warmth of urban runoff may be reduced by stopping water in underground retention areas or ponds. Pond depth and shading will determine how effective this is. You can reduce the temperature of stormwater from large commercial areas by painting roof surfaces in light, reflective colours and by shading parking areas with large trees.

Recommended Temperature Ranges

The Australian and New Zealand Water Quality Guidelines For Fresh and Marine Waters (ANZECC, 1992) recommends that the maximum permissible increase in water temperature should be less than 2°C. Aquatic organisms can be stressed when the temperature changes by more than 2°C in a 24 hour period.

Observe the trend of temperature changes over the seasons and note any temperature that is out of your normal range. Investigate the possible causes of unusually high or low temperatures. In estuarine waters temperature may change between an incoming tide (decrease) and on outgoing tide (increase).

The Resource Management Act (1991) limits temperature increase to less than 3°C.

Water Clarity

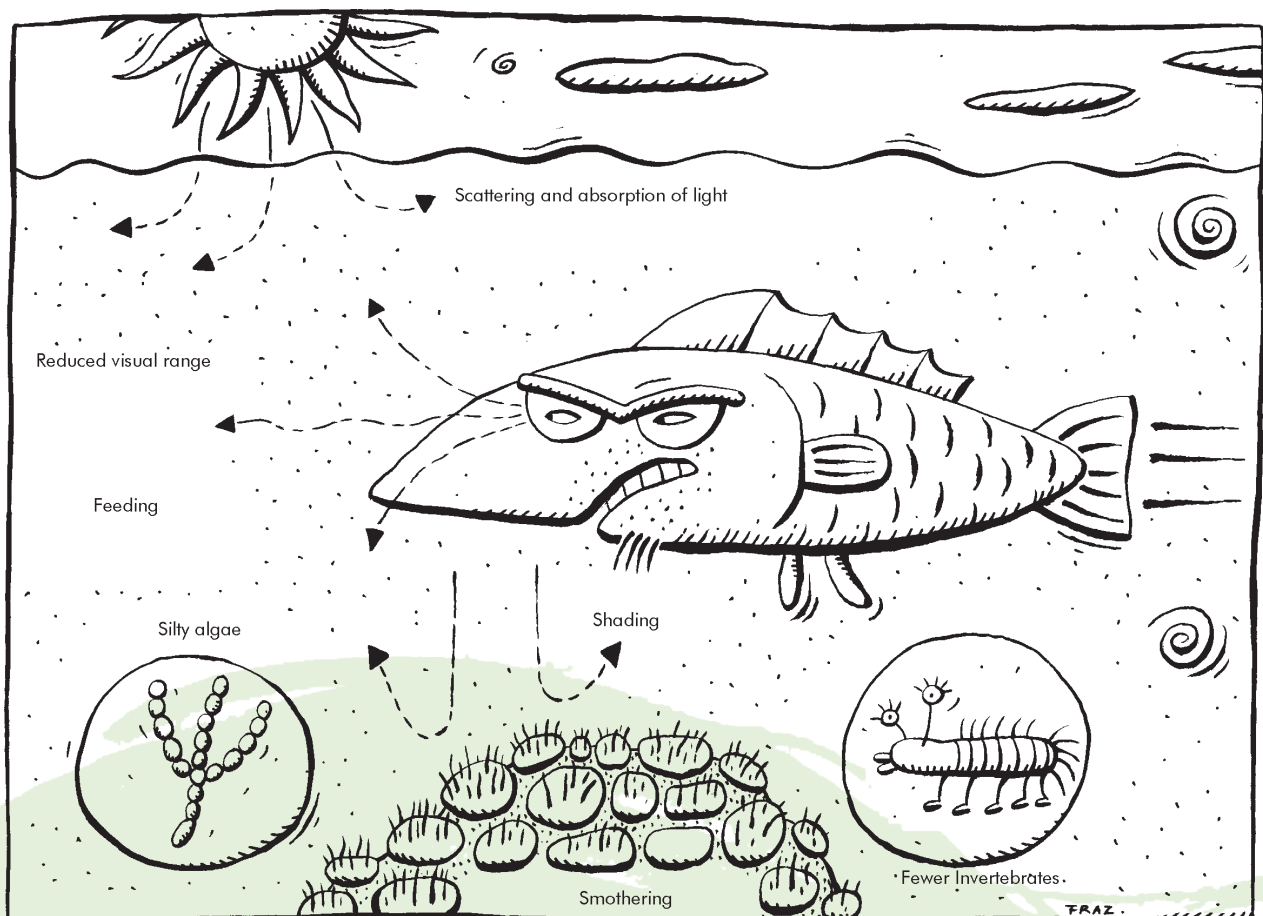
As erosion occurs within a catchment, tiny particles of clays, silts or small organic particles are washed into waterways. These tiny particles can be supported in the water current and are termed suspended solids. The faster the water is moving the more suspended solids it can carry.

Water clarity is an indirect measurement of the amount of suspended particles in water. In New Zealand it is the preferred method for assessing water turbidity or 'murkiness'. In other words, high water clarity means low turbidity and vice-versa.

New Zealand has some of the clearest and cleanest water in the world. The quality of our water contributes greatly to our economy, particularly through tourism. Water clarity is specifically included in the Resource Management Act 1991 because it affects the recreational quality of water and how people perceive it.

Soil type in the catchment can affect water clarity. For example, streams in catchments with clay soils are likely to have much lower water clarity naturally than streams in sandy catchments. Measuring the increase in suspended solids murkiness in a stream following rainfall is one way of assessing catchment condition.

In slow-flowing lowland streams, high levels of turbidity may persist for long periods. This is due to the slow rate of flushing and the fact that very fine particles are held in suspension almost indefinitely.



Importance

Suspended solids in a waterway can ruin habitat for fish and other aquatic life. The suspended material prevents light passing through the water column. Reduced light can limit plant growth. This in turn affects the fish and invertebrate communities that feed on and live in the plants. High levels of turbidity can damage water and aquatic organisms:

- Where there is less light penetrating the water, there will be less photosynthesis and this can reduce the level of oxygen in the water.
- The water becomes warmer because any suspended material absorbs heat from the sun. This also decreases the amount of oxygen dissolved in water (cold water holds more oxygen). Shaded waterways will be less affected.
- Sediments may cover eggs and benthic (bottom dwelling) creatures. The gill surfaces of many aquatic organisms are easily clogged by sediments, reducing their ability to take up oxygen. Death rates depend on how long and how bad the sedimentation is.
- Suspended sediment can carry nutrients and pesticides throughout the water.
- The fine particles settle in slower-moving downstream areas, filling in the spaces between rocks and gravel making the bottom habitat unsuitable for many animals.
- Poor water clarity has direct effects for the many fish and birds that use their sense of vision to find and catch their prey.

Other Sources Of Reduced Water Clarity

There are many possible sources of turbidity. On farms, several things may be responsible: cultivation too close to the stream edge, stock in the stream and bank collapse. Stormwater outlets from urban areas may carry heavy loads of sediment where they drain areas being developed.

Microscopic plankton also contribute greatly to turbidity when too many nutrients and sunlight increase their numbers.

You can usually find out where suspended solids come from on stream walk observations, microscopic examinations (for algae) or from changes in the colour of the water. Water colour can be defined accurately by comparing its colour to an 'apparent colour' chart.

Controlling Loss Of Water Clarity

You can reduce or avoid loss of water clarity by:

- Keeping vegetation along stream margins to stabilise banks.
- Providing culverts or bridges at stock crossings.
- Fencing stock away from waterways.
- Reducing water runoff from farm track watertables by using drainage channels or culverts leading to grassed areas or other ways of filtering.



- Minimise soil erosion from areas prone to damage from stock. Different amounts of grazing or types of stock e.g. sheep or calves rather than cattle, may be appropriate at different times of the year.
- Controlling stormwater flow from urban areas, especially new subdivisions by using silt traps.
- Avoiding pollution of waterways through the discharge of organic wastes, including sewage.
- Treating industrial effluents before they are discharged through sedimentation ponds or clarifiers.

Recommended Levels Of Water Clarity/Turbidity

The ANZECC (1992) Guidelines recommend that suspended particulate matter should not increase beyond 10% of the seasonal average concentration at a site nor change more than 10% between two sites on the same river with the same geology.

Australian authorities consider a result of 30 NTU is cause for concern. At that level they start investigating the cause of the turbidity.

The appearance of water usually determines how acceptable it is for different uses. Values above 5 NTU , or black disk visibility less than 1.6m, make it difficult for swimmers to see their feet when standing. These levels are now the limit for contact recreation purposes and enjoyment. Clarity levels worse than these are thought to be damaging to aquatic ecosystems.

To understand your results you need to get information about the natural levels of turbidity in your area at various times of the year. Natural variations within a district may be related to soil type and events such as flood flows. Different catchments will vary in their response to floods.

Interpretation of variation and baseline levels should take into account, not only the natural features of the area but also information about local land use practices and riparian management. You need a sound knowledge of the local catchment before you can decide what is causing turbidity.

Nitrogen

Nitrogen occurs naturally at low concentrations in surface waters. Under these conditions, decaying plant material and other organic matter provides much of the nitrogen.

Blue-green algae, the primary component of algal blooms, may introduce more nitrogen to the ecosystem by biologically converting gaseous or atmospheric nitrogen to usable forms.

In natural waters nitrogen is found dissolved, in particulate or in gases:

- **Dissolved:**

It may be present in the inorganic forms of nitrate, nitrite and ammonium; or in combined forms such as proteins and humic acids.

Nitrate (NO_3) is usually the most common form of nitrogen in water and is very easily taken up by plants.

Nitrite (NO_2) generally occurs at very low levels in most waters but levels can increase after discharges of some organic or industrial wastes, particularly where oxygen is in short supply. Nitrite is poisonous to animals and may cause cancer.

Ammonium (NH_4) is produced by the decaying of organic waste and most often changes to nitrate. This conversion process uses up oxygen, so therefore ammonium can exert its own biochemical oxygen demand.

- **Particulate:**

Small bits of undecomposed organic material, algae and soil particles have varying amounts of nitrogen in them.

- **Gases:**

These include nitrogen gas (N_2) and ammonia (NH_3). Ammonia can be acutely or chronically toxic to some species of fish and invertebrates.

Importance

Nitrogen is a mineral nutrient, essential for all forms of life. It is found in proteins, including enzymes, DNA and many of the other building blocks of life.

Aquatic organisms can use both dissolved and some particulate organic forms of nitrogen. The delicate balance of an ecosystem can be upset when nitrogen levels become too high. This can result in algal blooms and too much growth of aquatic weeds. When these plants die, they are decayed by oxygen demanding bacteria, which may remove oxygen from the water. Changes in how much oxygen is available may reduce the variety of invertebrate species, or in severe cases, kill fish.

Nitrates in drinking water can be dangerous to bottle fed babies under six months old. When nitrates are swallowed they are changed to nitrites in babies' digestive systems. Nitrite interferes with the oxygen-carrying capacity of blood and in severe cases may cause 'blue baby syndrome'.

Other Sources Of Nitrogen

Excessive amounts of nitrogen in water supplies is a major pollution problem.

High concentrations of nitrogen in water bodies can be the result of human activities:

- Nitrogen-fixing, legumes (e.g. clover) produce nitrates that 'leak' out of the root system and into the soil. Nitrates originating from legumes are often the most significant source of nitrate contamination within agricultural catchments.
- Using too much fertiliser has resulted in high levels of nitrates in the groundwater underneath some cropped areas in New Zealand. How much is lost by seepage is often determined by how much and how often water is applied.
- Runoff from intensively grazed paddocks and livestock feeding areas will contribute both nitrates and ammonia from animal wastes (mostly urine) to nearby waterways.
- Stormwater runoff can contain nitrates from lawn and crop or pasture fertilisers.
- Inadequately treated sewage from wastewater treatment plants or poorly functioning septic systems can be high in nitrates.
- Decaying organic matter, including silage, produce nitrogen-rich leachate.
- Some industrial discharges contain large amounts of nitrogen.
- Recreational activities such as swimming, boating and fishing can contribute nitrogen to streams through body contact, discarded food wastes, fish cleaning, etc.

Controlling Nitrogen Levels

- **Manage soil organic matter:**

A well-established pasture soil may contain more than 6000kg organic nitrogen per hectare. Ploughing accelerates the breakdown of this organic matter and the conversion of organic-N to nitrates.

- **Manage nitrogen fertilisers:**

Manage pasture, with clover as a source of nitrogen. Heavy applications of nitrogen fertilisers reduces the ability of clover to 'fix' nitrogen. Avoid heavy applications of nitrogen fertiliser, particularly in late autumn and winter. Use split doses to reduce losses from leaching.

- **Manage irrigation:**

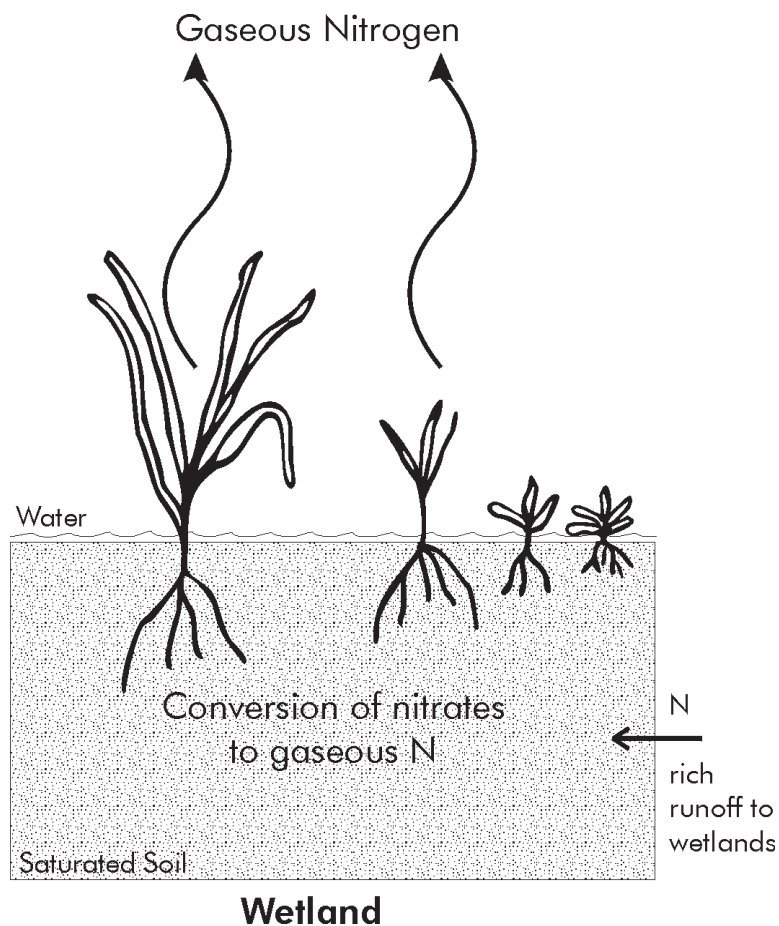
Maintain soil moisture levels in the best range for plant growth. Too much water cools soil, reduces aeration and leaches nutrients from the soil.

- **Manage effluent:**

Effluent irrigation systems are effective if the land area used is large enough and you avoid areas next to waterways. Oxidation ponds need managing and monitoring to ensure they do not contribute to pollution of waterways - they are by no means fail-safe.

- **Enhance wetlands:**

Most nitrate in ground waters passing through wetlands is removed by denitrification. Denitrification is a microbial process, which results in nitrates being converted to gaseous nitrogen. Wetlands are often found naturally near stream margins at the end of preferred drainage pathways.



Recommended Levels Of Nitrate

Unpolluted water generally has nitrate levels below 1mgL^{-1} . The Ministry of Health guidelines for drinking water are set at less than 50mgL^{-1} nitrate (11.3mgL^{-1} nitrate-N). Drinking water containing too many nitrates can cause methaemoglobinaemia in bottle fed babies. Small aquatic organisms are also sensitive to raised nitrate levels, by differing amounts.

Phosphorus

Phosphorus is a nutrient that occurs naturally at low concentrations in water. Under these conditions most of the phosphorus comes from the weathering of rocks and decay of leaf litter or other organic matter.

In natural waters, phosphorus occurs in dissolved or particulate forms:

- **Dissolved**

It may be present as simple inorganic 'reactive phosphate' (also referred to as 'orthophosphate') or as more complex forms of phosphate, such as organic phosphorus excreted by organisms.

- **Particulate**

These include phosphorus bound to clay minerals suspended in the water, or deposited on the stream bed as sediment, precipitates and phosphates occurring in living and dead organisms.

Importance

Phosphorus is an essential element for life; it is a plant nutrient needed for growth and part of many of the molecules responsible for life processes in plant and animal cells.

In most waters, phosphorus limits growth because it is present in very low concentrations. This is because it is attracted to organic matter and soil particles. Algae and larger aquatic plants rapidly take up any remaining 'free' phosphorus, in the form of inorganic phosphates.

When phosphorus levels exceed what is needed for normal plant growth, a process called eutrophication takes place. The nutrient-rich water stimulates plant growth, resulting in problems such as algal blooms and growths. When plants and algae cells die, oxygen is used in the decay and fish are often killed. Rapid decay of algae scums and decaying animal life causes foul odours, toxins and hydrogen sulphide gas.

Other Sources Of Phosphorus

The presence of too much phosphorus in water supplies can create a long-term pollution problem.

Increases in phosphorus levels in streams are most often caused by humans:

- Most of the phosphorus in soils is bound to soil particles or part of soil organic matter. Stream or riverbanks that are not planted or regularly damaged by stock are prone to erosion. Surface runoff may also put soil particles into waterways, particularly from areas that are regularly cultivated or disturbed.
- Discharge of sewage effluents and some industrial wastes.
- Detergent from domestic and commercial sources.
- Urban stormwater and rural runoff containing fertilisers and animal and plant material.

Under certain conditions high levels of phosphorus in water may come from bottom sediments, where they may have gathered over many years. For this reason, reducing phosphorus may not reduce such things as algal blooms for some years.

Controlling Phosphorus Levels

- **Runoff**

Runoff from urban and rural areas contains P bound to soil particles. You can reduce or avoid runoff by planting cover crops, contour ploughing, minimising soil disturbance (including conservation tillage) and retiring land prone to erosion.

Riparian strips and silt traps are the last line of defence and their long-term effectiveness is limited by how much sediment they can store. The accumulated sediment must eventually be removed. Farmers now use many of these practices but most urban developers have been slow to recognise their benefits.

- **Sewage**

Sewage treatment plants often provide most of the available P to streams and rivers. An adult person excretes about 1.5g of P per day and most of this will end up in the waterway unless the wastewater receives 'tertiary' treatment (primary treatment removes 10% and secondary about a further 20% of the phosphate).

- **Industrial products**

Avoid buying products such as toothpaste, detergent and washing powders containing phosphates. Many pharmaceuticals and food treatment products also contain phosphorus.

Recommended Levels Of Phosphorus

Maintaining aquatic ecosystems is the most important aspect of phosphorus concentrations in surface waters. In freshwater ecosystems too much phosphorus, rather than nitrogen, is often the trigger for problems such as algal blooms.

Total phosphorus levels higher than 0.03mgL^{-1} contribute to increased water plant and algae growth (eutrophication). Total phosphorus levels above 0.1mgL^{-1} may stimulate plant growth sufficiently to exceed natural eutrophication rates.

Rural and urban dry weather water quality should be less than 0.05mgL^{-1} total phosphorus.

Phosphates are not an issue in drinking water.

The ANZECC (1992) Guidelines recommend the following range for total phosphorus in different waterbodies to prevent eutrophication:

Rivers and Streams	$0.01 - 0.1\text{mgL}^{-1}$
Lakes and Reservoirs	$0.005 - 0.05\text{mgL}^{-1}$
Estuarine Waters	$0.005 - 0.15\text{mgL}^{-1}$
Coastal Waters	$0.001 - 0.01\text{mgL}^{-1}$

Dissolved Oxygen

Dissolved oxygen (DO) is the small amount of oxygen gas dissolved in the water. This oxygen is vital to fish, other aquatic animals, micro-organisms and plants which depend on it for the process of respiration, i.e. to 'breathe'.

The DO level is a useful general indicator of water quality. It can indicate the presence of certain pollutants, particularly organic matter. Sewage effluent, decaying aquatic vegetation and animal manures reduce DO levels as they are decomposed by micro-organisms.

DO levels in natural waters depend on four factors:-

- **How quickly oxygen is absorbed into the water from air**

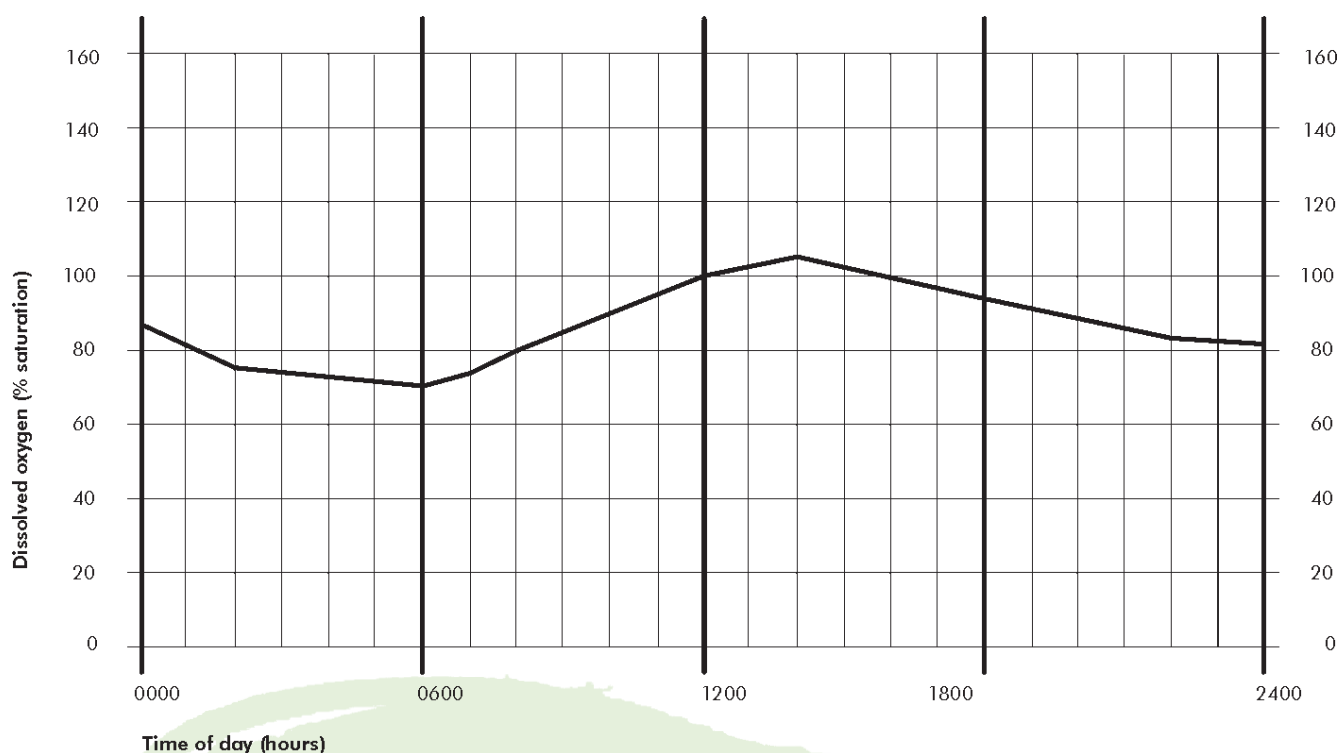
This depends on agitation at the water's surface. Shallow fast-flowing streams usually have high oxygen levels while stagnant pools usually have reduced oxygen levels.

- **How quickly oxygen is used up by organisms in the water**

Bacteria use up oxygen in water. If large amounts of organic matter enter the waterway the bacteria population will increase as will their consumption of oxygen.

- **Photosynthesis of plants and algae**

Aquatic plants and algae release large amounts of oxygen into the water in daylight hours as a by-product of photosynthesis. Peak DO levels occur in early afternoon and minimum levels before sunrise.



- **Flow variations**

Under very low flow conditions the DO levels may be less, particularly if surface agitation is reduced or the water temperature increases (colder water holds more oxygen). Flood events may increase DO levels but once the flood recedes the bacterial breakdown of organic debris left by the flood can lower oxygen levels for days or even weeks.

Importance

Waterways that have adequate levels of dissolved oxygen usually contain a wide variety of aquatic life. Reductions in DO levels result in the loss of the more 'sensitive' species, which include mayflies, stoneflies and caddisflies. At very low DO levels, there may only be a very few tolerant species such as sand fly larvae, but they are often abundant. The number of nuisance algae and organisms that at low oxygen levels may also grow.

Other Sources Of DO Variation

Adding organic matter to waterways often lowers DO. The cumulative effect of different sources can be substantial.

- **Point sources**

Sewage plants, animal feedlots, urban runoff, agricultural processing industries (e.g. meat works, dairy factories and pulp and paper) and poorly designed or managed oxidation ponds may contribute organic pollution in some catchments. These discharges are the easiest to detect and monitor.

- **Non-point sources**

Agricultural wastes are particularly important because agricultural land dominates the land surrounding most streams. Waste production from farm animals in New Zealand equals the output of a human population of 153 million people. Animal wastes may enter streams with surface runoff, farmyard washings and at stock crossings.

Leachates from silage pits that get into nearby waterways provide a rich source of organic matter for bacterial decay.

Leaves falling into streams may be important where riparian vegetation is mostly deciduous. Debris left behind from logging operations may also lower oxygen levels. This rotting material determines the change in the DO level.

Spraying aquatic or streambank weeds by some local councils and farmers can also add substantial quantities of decaying matter to streams.

Urban stormwater runoff may contain organic matter from many places, including garden wastes, sink disposal systems and food processing industries.

Controlling DO Variation

Point source discharges from farms, industry and urban areas have improved considerably in recent years with systems that minimise or avoid organic contamination of waterways:

- Using land irrigation system for effluent disposal on farms. It is important that the irrigation outlet is shifted to different paddocks on a regular basis.
- Dairy farms still using oxidation ponds have mostly adopted the two-pond effluent treatment system.
- With few exceptions industrial discharges are under control and incidences of organic pollution are uncommon and mostly due to accidents such as operator error.

- Improved sewage treatment systems that decompose most of the organic waste before it is discharged into waterways. 80 percent of New Zealand households are connected to some type of sewage treatment system. However, many systems are antiquated and are prone to stormwater invasion. This may result in untreated sewage escaping or reducing the effectiveness of treatment.
- Positioning of farmyards, farm tracks and holding pens away from streams will lessen runoff contamination.
- Controlled dumping of organic wastes at rubbish dumps, away from drains and streams. As this matter rots, you can expect leachates to drain.

Non-point sources of pollution are more difficult to control. These methods help:

- Fencing off or retiring riparian areas to keep stock out of and away from waterways.
- Shading waterways with riparian plantings reduces weed growths in and beside the channel, making herbicide sprays unnecessary.
- Avoiding stimulating excessive weed or algae growths. Eventually more plant growth leads to more plant decay. Preventing nutrient enrichment and increased light and temperature levels in the waterway needs a combination of positive management practices. See the sections dealing with temperature and nutrients.
- Screen or process stormwater runoff to remove organic matter.

Recommended Levels Of Dissolved Oxygen

The ANZECC (1992) Guidelines recommend that for the protection of freshwater and marine ecosystems, Dissolved Oxygen levels should not fall below 80-90% saturation. Results less than 110% saturation indicate that algal photosynthetic activity is producing too much dissolved oxygen.

DO levels below 2mgL^{-1} will not support fish life. DO levels below 3mgL^{-1} stress most aquatic organisms. At least $5\text{-}6\text{mgL}^{-1}$ are needed for fish growth and activity. The DO level in good fishing waters generally averages about 9mgL^{-1} . There are no health-based guidelines for human or livestock consumption.

A dissolved oxygen test tells us precisely how much oxygen is dissolved in water, but it does not indicate how much DO the water is capable of holding at the test temperature of the water. The percentage saturation is a better measure of how much oxygen is available to aquatic organisms.

Flow Rate Of Streams

The flow rate of your stream will influence water temperature, the concentration of dissolved oxygen and how many solids can be kept in suspension. The average rate of flow is an important factor in determining which particular plants and animals will find suitable habitats in a stream reach. Refer to the aquatic habitat section of 'Conducting Biological Surveys'.

Rain, through its effect on how often and how large floods are, is a most important factor affecting rivers and streams. Large catchment scale features such as geology, soil type, catchment slope and the degree of forest cover mostly affect flood flows.

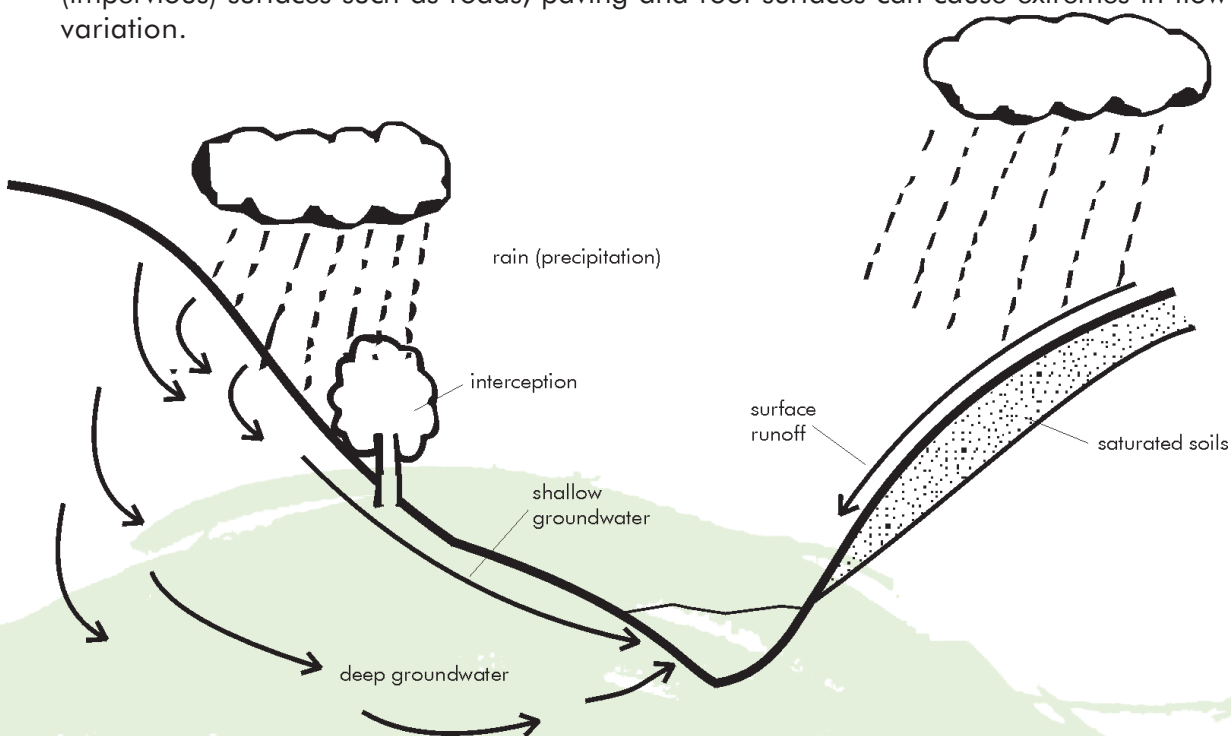
Importance

Higher than normal flows may disrupt communities of aquatic organisms, flush away algae and macrophytes (aquatic plants) and increase sediment levels. Lower than normal flows can increase temperatures, lower oxygen levels, concentrate nutrients and increase algae and plant growth.

Ideally, carry out your monitoring when the waterway is at or near typical levels. Take any difference into account when interpreting results.

Other Sources Of Variations In Flow Rate

- The type of vegetation in the catchment can alter runoff into waterways. Native and exotic plantations can store a large amount of water, reducing the amount and speed of water entering the stream or channel. In rural areas, wetlands are vital in interrupting overland flows (runoff) and can help reduce changes in the amount of seasonal flow.
- Changing a stream channel (channelisation) may increase the speed of water moving through a waterway, creating high-energy peak flows. Damage to stream banks and aquatic ecosystems often depends on how much the channel has been changed. Stormwater runoff from solid (impervious) surfaces such as roads, paving and roof surfaces can cause extremes in flow variation.



Water that has not been intercepted and lost back to the atmosphere is either stored temporarily in the ground (groundwater) or appears as stream flow.

Controlling Flow Variation

It is unlikely that changing land management practices will reduce the total flow of streams, but it is possible to reduce flow velocities (and therefore erosive power) during floods and minimise low flows:

- Increase the 'roughness' of the channel above the low flow level (i.e., up the stream/riverbank) and on the flood plain. Plantings in these areas will increase drag and slow water down. Some localised flooding may occur as a result.
- Change surface runoff speed with strategically placed riparian plantings. Dense ground cover such as grasses and sedges are most effective for slowing overland flows.
- Maintain existing stands of bush to reduce run-off and erosion.
- Avoid changing the path of waterways to increase flow/drainage rate.
- Put back meanders where channel straightening has happened.
- Direct farm track/road run-off away from waterways. Direct flows through grassed areas or other absorbent system.
- Install headwater farm retention dams.
- Retain or re-establish wetland areas. Runoff stored in wetlands is slowly released after the flood peak has passed.
- Reduce taking water during periods of low flow. Most water consents state the percentage of the flow that can be taken.
- Use soak holes or baffles to reduce the energy and speed of stormwater run-off.

By reducing localised flooding in headwaters it is likely you can minimise risk of large scale flooding in lowlands. Reduce the risk further by holding less water within the watercourse in these lowland areas:

- Avoid blocking or damming waterways.
- Provide shade along stream margins to reduce nuisance weed growths which restrict flow.

Wetlands are also important in lowland areas, reducing further inflows by interrupting overland flows and seeps.

Improving Accuracy

1. Calculating your stream's cross-sectional area in segments

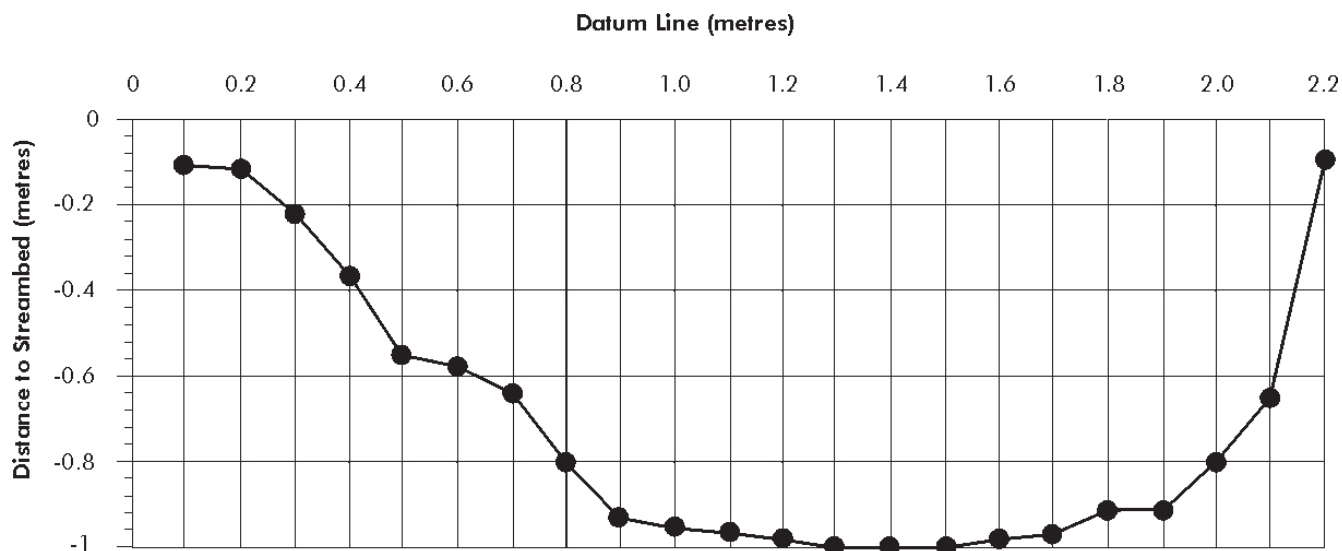
By dividing your stream cross-section into segments you will be able to take account of changing flow velocity across the channel. The area of each segment of the profile can be determined by multiplying the width (interval) by the average depth at each side of the measured interval.

Area of each segment = width x average depth

Add up the total of these segments, as shown in the formula below:

Cross-sectional area = [A (width) x a (average depth)] + Bb + Cc + Dd... etc - [number of readings]

From your recorded measurements draw the drain or stream cross-section on graph paper as shown in the diagram on the next page.



2. Measuring stream velocity

- Add the velocity readings at each side of the segment and divide by 2. This will give you the average velocity for the segment and allow you to calculate the flow contributed by each of the stream segments.

Use a table based on the one below to work out stream flow:

Segment number	Width of segment	Depths each side	Average depth	Area of segment	Height of head each side	Average head in segment	Average velocity in segment	Flow in segment
	(A)	(a1 & a2)	(a)	(A x a)	(h1 & h2)	(h)	(4.43h)	(area x velocity)
1								
2								
3								

- The choice of float can influence the results. An orange works well because it floats roughly in the zone of maximum velocity, just below the surface of the water. Another type of float may be needed in shallow water where an orange will get snagged.

To estimate the stream velocity as close to reality as possible, you need to multiply the velocity obtained from the orange moving in the fastest part of the stream by a correction factor. This allows for the total flow being uneven: it is slower at the edges than in the middle, and varies also from the surface to the depths.

For oranges use a correction factor of 0.8:

$$\text{corrected velocity} = \frac{\text{distance travelled (metres)} \times \text{correction factor}}{\text{average time taken (seconds)}}$$

Recommended Flow Velocity Levels

Sensitive stream organisms are generally unable to tolerate velocities less than 0.1m/s due to reduced oxygenation of the water. Slow moving water also tends to heat up more, making it worse. Shaded rocky-bottomed streams are less affected by low flows.

Moderate to fast flow rates (0.3 to 0.7 m/s) are preferred by most macroinvertebrates and speeds greater than 0.3 m/s prevent rooted water plants from reaching nuisance levels.

Calculating Sediment and Nutrient Loads and Losses

Once you have calculated stream flow and determined nutrient concentration or sediment load you can find out how much of any substance, such as nitrogen or phosphorous, is actually being 'exported' by the water and lost from the land.

The transport rate of substances in the water is measured in milligrams per second or kilograms per day.

To calculate the transport rate of a substance multiply the flow rate of the water by the concentration of the substance.

For example, if a site has a flow rate of $1.2\text{m}^3\text{sec}^{-1}$ and a nitrate concentration of 0.03mgL^{-1} , the load of nitrate through that site per day can be calculated:

1. Convert flow rate to litres per second

1 cubic metre of water = 1000 litres

Therefore

$$1.2\text{m}^3\text{sec}^{-1} = 1200 \text{ Lsec}^{-1}$$

2. Transport rate (per second)

= Flow Rate x Nutrient Concentration

$$= 1200 \text{ Lsec}^{-1} \times 0.03 \text{ mgL}^{-1}$$

$$= 36 \text{ mgsec}^{-1}$$

3. Transport rate (per day)

To convert mg per sec to kg per day multiply by 0.0864 (conversion factor)

$\frac{\text{Number of seconds per day}}{\text{Number of litres in a megalitre}}$ <p>i.e. $\frac{60 \text{ sec} \times 60 \text{ min} \times 24 \text{ hour}}{1,000,000} = 0.0864$</p>

$$= 36\text{mgsec}^{-1} \times 0.0864$$

$$= 3.1\text{kg per day.}$$

Calculating how much is lost from the catchment

Estimate the catchment area using a contour map. Divide by the area of the catchment contributing to that part of the stream and you can estimate the loss rate per hectare. Catchment loss rates allow you to compare one section of a waterway with another section, or one waterway with another according to their land use and soil-type.

Loss rate

$$\text{Loss rate (grams per hectare per hour)} = \frac{\text{load (g per hr)}}{\text{catchment area (hectares)}}$$

For example, the loss rate **per hour** for a sub-catchment of 63ha, with a transport rate as calculated above (36mgsec^{-1}), would be as follows:

$$\text{Loss rate} = \frac{36}{63\text{ha}} = 0.57\text{mg per ha per sec}$$

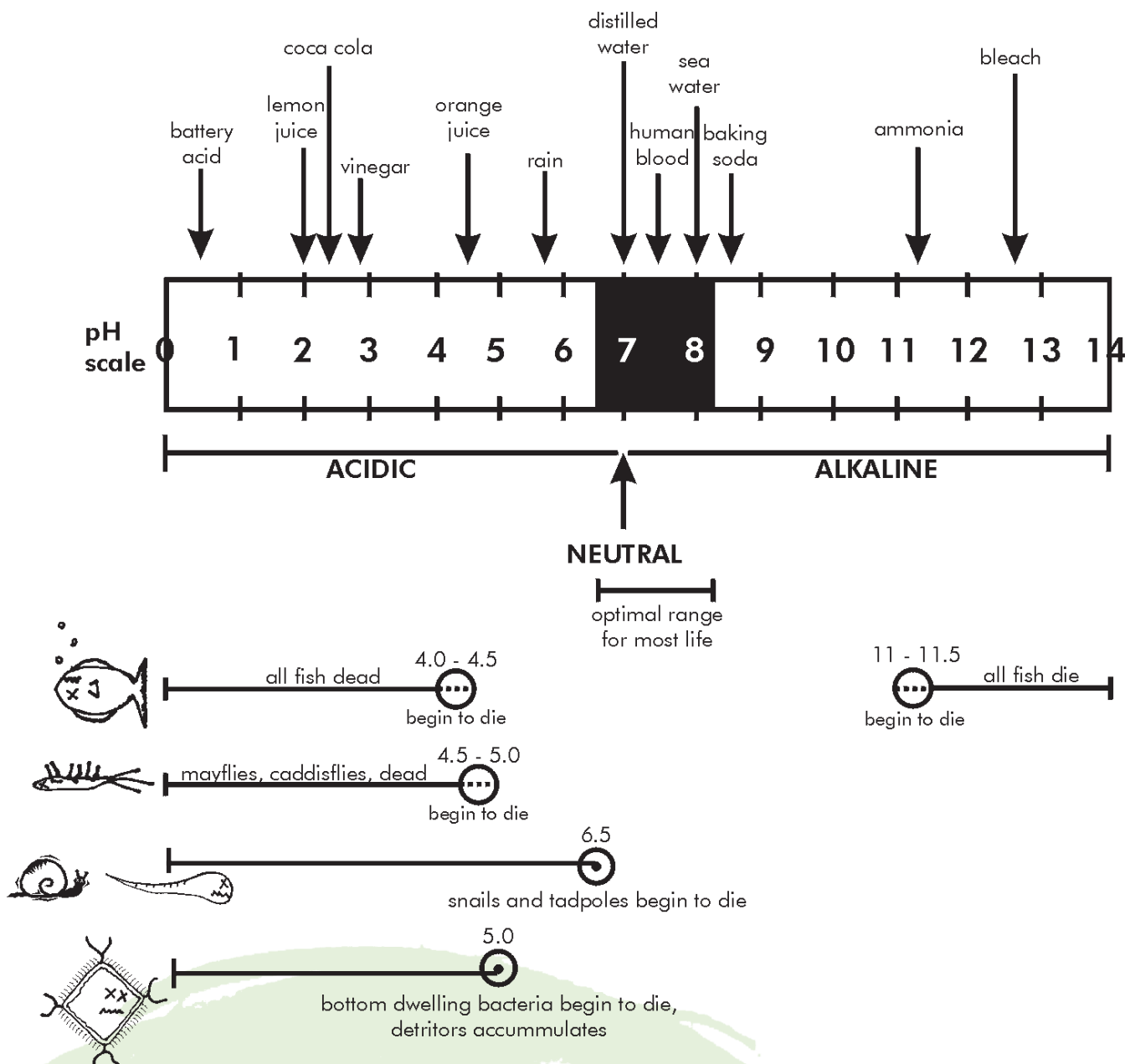
To convert to grams per hour, multiply mg per sec by 3.6 (i.e. $60 \times 60/1000$)

$$\text{Loss rate} = \frac{36 \times 3.6 \text{ g per hr}}{63\text{ha}} = 2.06\text{g per ha per hr}$$

pH

The pH of a stream is a measure of how acidic or alkaline (basic) the water is on a scale of 0 to 14. Pure distilled water (H_2O) contains only H^+ and OH^- ions, in equal proportions, and has a neutral pH (pH 7).

pH measurements below 7 indicate the solution is acidic and the solution contains more H^+ ions than OH^- ions. Measurements from 7 to 14 indicate alkalinity and the water contains more OH^- ions than H^+ ions. It is important to remember that for every one unit change on the pH scale, there is approximately a ten-fold change in how acidic or alkaline the sample is.



- **The pH of natural waters is largely determined by the geology and soils of the catchment**

The pH of fresh waters is usually 6.5 to 8.2, although wide variations can occur because of catchment geology. Water from limestone areas has relatively high pH levels. In contrast, streams from the central volcanic zone are often very acidic because sulphurous geothermal fluids flow into them.

Streams draining large wetland areas, peat swamps and coastal dune areas may also be acidic due to the presence of acids from the breakdown of organic matter (humic acids). Straw-coloured staining of water often indicates the presence of humic acids.

Stream water can often 'mop up' small increases in H^+ (hydrogen ions). Water from limestone areas, containing carbonates, can mop up the most.

- **Photosynthesis by aquatic plants and algae can cause significant variations in pH**

During the day dissolved carbon dioxide (which causes acidity) is taken up by the plants. The pH values are usually highest (least acidic) at mid-afternoon.

Measurements of pH tell us a lot about the natural condition of a water body as well as indicating whether it is being polluted.

Importance

Animals and plants in streams are adapted to certain ranges of pH. Even under natural conditions, the animal and plant communities of acid streams contain many different species to those in alkaline streams. Changes in pH outside the normal range of a water body will cause more sensitive species to die. Extremely high and low pH values will kill all aquatic life.

Changes in the water's pH can affect aquatic life by changing other aspects of the water chemistry. For example, water containing ammonia becomes vastly more toxic as pH values creep into the alkaline range (causing ammonium to convert to the toxic form, ammonia).

Other Sources Of Variation In pH

- The most significant potential change in the pH of water happens where acid sulphate soils are exposed to the air by mining or urban development. During heavy rain, these acids could be washed into streams causing sharp drops in pH for short periods. Mining companies operate under stringent controls to prevent acid mine drainage.
- Exhaust emissions, containing both nitrogen oxides and sulphur dioxide, can be extreme near motorways. When it rains these gases combine with water in the atmosphere to form nitric and sulphuric acid. The acid rain may have a significant impact on streams receiving runoff.
- Nutrient pollution can cause excessive growth of algae and other plants and raise pH to quite high levels at certain times of the day. These fluctuations in pH can sometimes be quite large and can reduce the number of species of aquatic organisms normally in the water.
- Some types of industrial discharges can cause significant changes in pH.

Controlling pH Levels

- In New Zealand coal and gold mining activities are strictly regulated and monitored. Water removed from mined areas is treated to remove contaminating substances, such as metal sulphates, before being discharged. Waste rock which can generate acid is contained deep within engineered dams to prevent contact with air. Dam embankments are usually built on top of a wide trench that has been cut down into impervious bedrock.
- Motorway runoff may be channelled to grassed areas or other filters. Grasses may need to be selected for their tolerance to acid conditions.
- There are many ways of reducing nutrients. Many are outlined in the phosphorus and nitrogen information sheets.

Recommended pH Levels

The ANZECC (1992) Guidelines recommend the following optimal ranges for pH values:

To protect freshwater aquatic ecosystems	6.5- 9.0
For recreational waters	5.0 - 9.0
For drinking water supply	6.5 - 8.5
For agricultural water uses	4.5- 9.0

Changes of more than 0.5 pH units from the natural seasonal maximum or minimum in freshwater should be investigated. Many freshwater systems have a pH close to 7.0. However, the range in limestone areas is 7.0 - 8.5 and in non-limestone areas 5.0 - 7.0. Very acidic conditions may occur naturally in some tributaries within the central volcanic zone.

Conductivity And Total Dissolved Solids

How water dissolves substances is one of its most useful properties.

Naturally occurring and artificially introduced chemicals may end up in water as it percolates through soils or rocks, changing its chemistry. Conductivity is one way to measure the amount of substances such as calcium, bicarbonate, nitrogen, phosphorus, iron, or sulphur dissolved in water. The test for Total Dissolved Solids (TDS) is a conductivity test of the available ions in the water. The probes on the TDS meter measure the flow of electricity created by the polarisation of these ions.

Conductivity provides only an estimate of the Total Dissolved Solids in a solution.

Importance

Raised levels of dissolved minerals may affect how suitable the stream water is for some uses, such as drinking water and protecting ecosystems. Some species of aquatic plants and animals tolerate only a small range in the amount of dissolved solids in water and they begin to disappear if levels rise.

Some species of macroinvertebrates are very sensitive to metal ion concentration and may be used as indicators for the presence of these ions.

Other Sources Of Conductivity And Dissolved Solids

- Variation in conductivity can be caused by changes in the geology of an area. Some tributaries of the Waikato River are highly mineralised from the flow of geothermal fluids from the Taupo Volcanic Zone and sustain aquatic communities. The detrimental effects of these minerals are largely corrected by dilution when these streams reach the river.
- Changes in conductivity can also be due to seepage of groundwater, industrial and agricultural effluent, stormwater runoff and sewage effluent flowing into the stream. Localised effects may be very noticeable and help trace where contamination comes from.
- Too many nitrates or phosphates will also result in higher conductivity readings and these ions can have a dramatic effect on ecosystems. See the section on eutrophication. Low levels of dissolved solids are vital to the growth of aquatic plants and animals.
- Water conductivity can vary significantly. Values are normally lowest during high flows and increase as flows decrease. Extreme amounts may occur during periods of drought.

Controlling Conductivity Levels

Dissolved solids from town runoff are difficult to deal with. Natural filters such as grassed areas may be used to strip nutrients from surface runoff but these soon become full and stop working properly. More complex and costly systems are being trialed by some councils and industries.

Fencing of banks in rural areas can achieve the same result as grassed areas. You can prevent nutrients building up by cutting forage and tree crops.

The most economical solution in most cases is to avoid contamination or take action to lessen the damage:

- Avoid applying fertiliser next to waterways. This can be difficult if you use top dressing. Most forestry companies have adopted a code of practice to protect waterways from top dressing.
- Avoid heavy use of fertilisers during late autumn and winter. Erosion, runoff and leaching are usually greatest then.
- Use split doses of fertilisers rather than single larger applications.
- Avoid putting too much fertiliser on lawns, and dumping organic wastes near waterways.

Recommended Levels Of Conductivity

Conductivity is measured with a meter in milli siemens per metre units (mSm^{-1}). The natural conductivity of fresh water varies from very low values (less than 3.0 mSm^{-1}) to very high values 25 or more mSm^{-1}), which may be unsuitable for irrigation. The average for New Zealand rivers is 8.5 mSm^{-1} .