Understanding the 'wet' in wetlands

A guide to the management of freshwater wetland hydrology

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Contents

1. Wetlands and hydrology – how do they fit together?

Freshwater wetlands need water to survive. The flow of water in and out of a wetland is known as its hydrology.

The hydrology of a wetland can be modified by human activities, such as drainage to make the land more suitable for pasture, or flooding to create bigger pond or lake areas.

In order to restore a wetland we need to understand how the water behaved before human intervention – and whether it is possible to get it to behave that way again.

This booklet tells you how you can monitor and understand the hydrology of a wetland and how you can establish a more natural water regime in a wetland that has been modified.

What is a wetland?

A wetland is an area of land covered in, or saturated by water.

Many New Zealand wetlands have saturated soils nearly all year round. The water level is either just above or just below the ground surface. In rare cases wetlands are only wet for a few weeks or months in a year; and may even stay dry for years on end.

Wetlands support a natural ecosystem of plants and animals that have adapted to wet conditions. They vary widely because of regional and local differences in soils, topography, climate, hydrology, water chemistry, vegetation and other factors, including human disturbance. All wetlands, however, have the following three things in common:

1. water
2. wetland soils (which have low levels of oxygen or none at all, because they are intermittently or permanently saturated)
3. wetland plants (which have adapted to growing in wet soil).

A description of the different wetland types is in Appendix 1.

Where are wetlands found?

Wetlands are found almost everywhere, from the tundra to the tropics and on every continent.

Wetlands flourish in areas with:

- fine-textured soils and poor drainage
- soils that are deep enough to store water
- restricted downward drainage.

Wetlands occur where the terrain, climate, soil and drainage conditions allow water to collect such as in land-surface depressions or other areas with excess surface water and poor drainage.

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Wetlands can be found:

- along hillsides where there is a change in slope or geology
- on stream or river floodplains
- in low-lying areas among flat landscapes
- in coastal areas where sand dunes trap water run-off
- along the margins of lakes, rivers and estuaries.

New Zealand – wetlands under threat

The appreciation of New Zealand's wetlands as important habitats for threatened native plants and animals, as well as for their role in flood protection, water storage and filtering run-off, is increasing. However, because their true value has not been fully understood in the past 200 years, more than 90% have been drained to make way for agricultural and urban development. We have one of the highest rates of wetland loss in the world.

Today, wetlands continue to be threatened by human activity. We need to protect what is left and take action to restore our remaining wetlands to a more natural state. To do this successfully, we must continue to develop our understanding of wetland hydrology.

What is wetland hydrology?

Hydrology is the science of water, and water is the driving force that creates and maintains all wetlands. Hydrology keeps our freshwater wetlands wet.

The term 'wetland hydrology' describes the water flow in and out of the wetland, as well as its quantities, flows and levels. Because water levels are so important for both wetland and catchment health, it's critical to understand a wetland's hydrology if we want to manage the wetland effectively and sensitively.

2. Why is wetland hydrology important?

It makes wetlands work…

Wetland hydrology determines:

- the amount of nutrients entering and leaving a wetland
- the chemistry of water in a wetland
- the chemistry of soil in a wetland
- the plants that grow in a wetland
- the animals that live in a wetland
- the productivity of a wetland.

Wetlands are an important part of the entire hydrological cycle – they soak up run-off and filter and release floodwaters gradually. This reduces the peaks of flooding and maintains flows in dry years.

It shapes what will grow…

The types of plants and animals in a wetland depend on the water – its volume, depth, permanence, temperature, and chemistry.

Long-term fluctuations in water level over months and years generally result in a species-rich wetland ecosystem.

Plants

Wetlands are a harsh and stressful environment for most plants. Those that grow in wetlands have had to adapt to growing in wet soils. For example, kahikatea and pukatea buttress their roots so they are stable in wet soils, while many smaller plants have spongy tissues in their leaves that act as a reservoir and passageway for oxygen to move down to the roots in wet, oxygen-deprived soils.

Raupo can grow in areas of deep water because of its ability to spread from underground rhizomes rather than seeds.

Some wetland plants are generalists and adapt readily to a wide range of conditions, while others thrive only in very specific habitats. Many spread without producing seeds (‘asexual reproduction’) and have underground storage organs that help them survive and re-grow rapidly after the sudden floods and prolonged droughts common in wetlands. Asexual reproduction also helps the plants colonise parts of wetlands where the water is too deep for seeds to germinate and establish successfully. For example, raupo dies back over winter and grows back in the spring from underground rhizomes (starch-filled stems).

When a wetland floods, the soil becomes saturated and drought-tolerant plants revive, while the seeds of water-loving plants germinate and grow. Where wetlands are flooded unnaturally, plant diversity can decrease because only a few species are able to grow in permanently deep water[1].

As water levels drop, different plants germinate and grow on the exposed mud. The soil chemistry changes as it is exposed to the air, encouraging dry land plants. Some wetland plants, such as *Carex*, set seed in summer when water levels are low. Often these seeds can stay viable in the soil for years even if the wetland is dry.

[1]Sorrell et al. (2004), in *Freshwaters of New Zealand.*

Animals

Wetland animals respond to seasonal fluctuations in water levels. When levels drop, many fish and eels retreat and water birds migrate. When water levels return, they trigger a flush of food (invertebrates) that brings the birds and fish back – waterfowl often take the opportunity to breed with so much food about. Mudfish have a different response to low water levels – they hibernate in the wet soil and wait for the water to return.

It affects nutrient levels…

A wetland's productivity mainly relates to the amount of carbon that plants fix during photosynthesis – a process that is enhanced by flowing water.

Some wetlands, especially swamps in valleys and depressions at the bottoms of catchments, have very high biological productivity because they offer few constraints to photosynthesis (they contain plenty of water and nutrients compared with ecosystems on dry land). Highly productive, fertile wetlands like this are fed with water containing sediment and nutrients, often from flooding rivers. Regular wetland drying and refilling increases the amount of nutrients released from the sediment and promotes the rapid decay of plant material.

At the other end of the scale, some wetlands have low nutrient levels and are very unproductive - for example bogs that are fed by rainfall only. They have simpler plant communities and slower decay of plant material, which accumulates as peat[2].

It influences the whole catchment…

Wetlands are an important part of the catchment hydrological cycle.

Depending where they are in the catchment, wetlands can soak up run-off and release floodwaters gradually, reducing the impact of flooding downstream. Those on river and stream floodplains have an important function in storing, transporting and slowing floodwaters. However, when wetlands are drained or stopbanks are built along adjacent rivers, their ability to store water is reduced and downstream flooding can occur[3].

[2] Campbell and Jackson (2004), in *Freshwaters of New Zealand.*

[3] NRC (National Research Council) (1992) *Restoration of Aquatic Ecosystems*. Committee on Restoration of Aquatic Ecosystems – Science, Technology, and Public Policy. Water Science and Technology Board. Commission on Geosciences, Environment, and Resources.

3. Wetland hydrology – the detail

Wetlands are dynamic hydrological systems whose water flows and levels can vary substantially, both seasonally and from year to year.

A wetland's 'hydrological regime' describes the patterns of water storage and movement within and across the wetland's boundaries. It can have strong seasonal patterns, largely the result of changing rainfall and sunshine intensity.[4]

A wetland's hydrological regime is determined by:

- the timing of the presence of surface water
- how often it floods and dries ('frequency')
- the length of wet and dry periods ('duration')
- how far the water spreads ('extent')
- the depth of surface water
- how far the water is below ground (the depth to the water table)
- the water's source (e.g. rainfall, groundwater)
- the variability of water levels (including depth and extent seasonally and from year to year).

Wetland inflows, outflows and the water balance

A wetland needs a continuous or seasonal source (inflow) of water. Table 1 summarises these inflows, as well as the outflows.

Table 1: A wetland's water sources (inflows) and water losses (outflows)

Water inflows	Water outflows
Rainfall • rain that falls directly onto the wetland	**Evapo-transpiration** • evaporation from standing water or saturated soils • transpiration from plants
Surface water • water run-off from surrounding land • streams and rivers that flow into the wetland • occasional flood waters from nearby streams and rivers	**Surface water** • water run-off from the wetland • streams and rivers that flow from the wetland
Groundwater • groundwater inflow	**Groundwater** • groundwater outflow

[4] Campbell and Jackson (2004), in *Freshwaters of New Zealand.*

The difference between a wetland's water inflows and outflows is known as its 'water balance'. When averaged over a long period, the inflows appear to balance the outflows. However, at any time, one or more components of the balance may dominate. For example, heavy rainfall will cause water levels to rise temporarily. Alternatively, if groundwater levels reduce, the wetland may dry up because groundwater inflows decrease.

Different wetlands are sustained by different inflows and outflows. For example, a bog is fed entirely by rainfall, while a swamp mainly receives its water from surface water and groundwater.

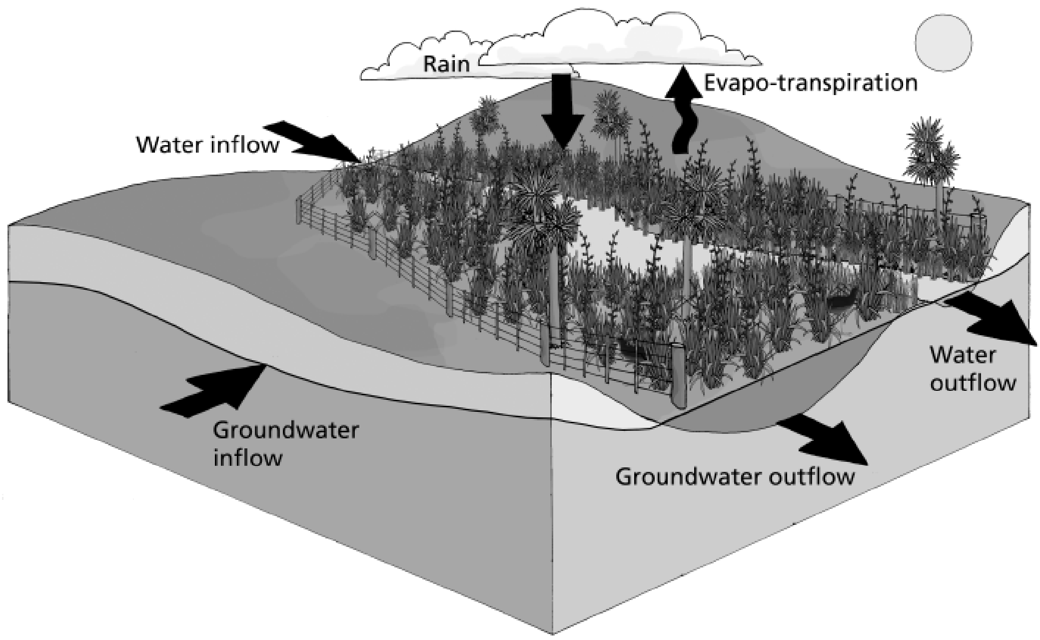

Figure 1: The factors making up a wetland's water balance (after Carter, V, 1996, Wetland hydrology, water quality, and associated functions. In National Water Summary on Wetland Resources. Water-Supply Paper 2425. United States Geological Survey. Washington, DC. http://water.usgs.gov/nwsum/WSP2425/)

Surface water

Many wetlands rely on surface water flows and are an integral part of river and stream systems. For example, they can be the source of a stream (in its headwaters) or fed by a stream, either permanently or only when the stream is in flood. Wetlands can also receive surface water as run-off from surrounding land.

Groundwater

Groundwater is an important part of the water balance for most wetlands. It affects wetlands in two main ways:

1. **Flowing in**: a 'discharge wetland' is created when groundwater flows (or discharges) into a wetland located in a topographic low point, where the wetland water level is lower than the surrounding water table (see Figure 2A). Discharge wetlands tend to be buffered against dramatic seasonal changes in water level. For example, wetland studies on the Kapiti Coast have shown that groundwater is important for keeping the soils wet at drier times of the year. A 'spring' or a 'seep' is another type of groundwater discharge wetland that occurs at the base of slopes where the water table intercepts the land surface (see Figure 2B)
2. **Flowing out:** a 'recharge wetland' is created when the water level in a wetland is higher than the water table in the surrounding area – the groundwater flows out of the wetland (see Figure 2C). However, where the amount of water flowing out of the wetland is negligible, the wetland is known as a 'perched wetland' (see Figure 2D).

The interaction between a wetland and groundwater can vary seasonally and even reverse during the year.

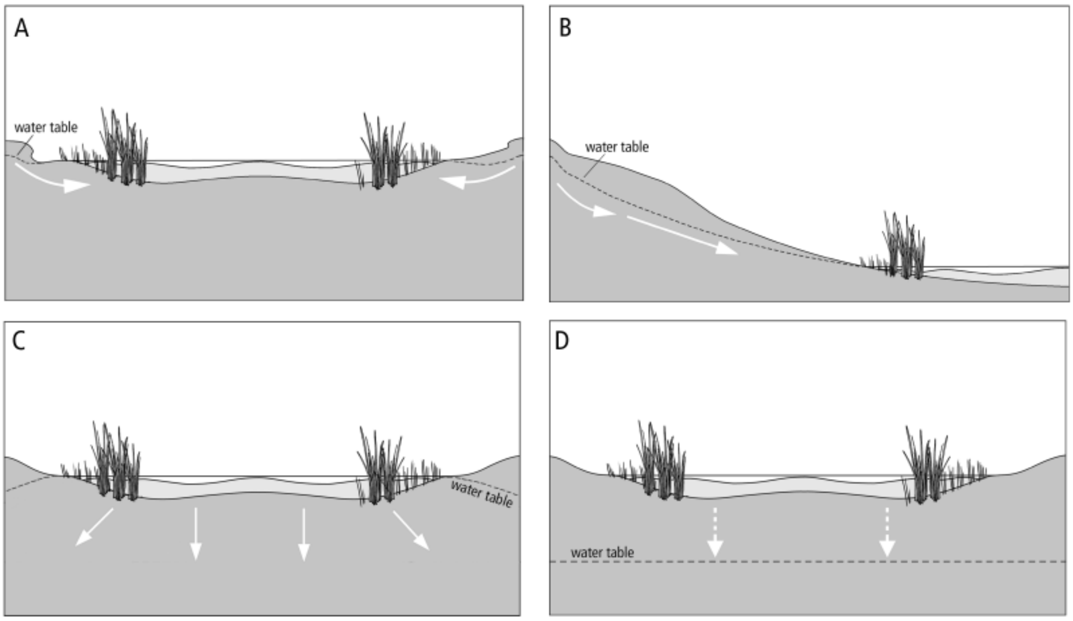

Figure 2: Some wetland/groundwater interactions. The arrows show the direction of flow.

A. Discharge wetland receiving groundwater inflow
B. Groundwater spring or seep wetland at base of a steep slope
C. A recharge wetland adding water to groundwater
D. A perched wetland with a small amount of groundwater recharge (after Mitsch and Gosselink, 2000).

Evapo-transpiration

Evapo-transpiration is the collective term for the ‘transpiration’ from plants and water that ‘evaporates’ to the atmosphere from open water or moist soils.

Evaporation and transpiration rates are mainly controlled by the sun (solar radiation and temperature), humidity and wind speed – they vary between night and day, from day to day, and seasonally. Vegetated wetlands usually have lower evaporation rates than open water wetlands.

Evapo-transpiration can be a large part of a wetland’s water balance and can reduce the amount of water flowing out, especially in summer. Its rates can be altered by:

- **grazing**: by removing vegetation cover, grazing increases evaporation from open water or wet soils
- **vegetation clearance**: this changes the local microclimate, which also influences evaporation rates
- **planting willows**: overseas studies show that willows have higher rates of transpiration than native wetland plants, providing a drying effect on wetlands.

For information about measuring evapo-transpiration in New Zealand wetlands, refer to the chapter on wetland hydrology in *Freshwaters of New Zealand* (2004) listed in Section 9 of this guide.

4. Human impacts on wetlands and wetland hydrology

Wetlands (and the plant and animal life they support) are sensitive to changes in water balance, hydrological regime, flood cycles, water quality, sediment and nutrient supply.

Most of New Zealand's wetlands have been lost over the past century because they have been drained for agricultural use. Many of the remaining wetlands are surrounded by intensively farmed land where drainage, large-scale irrigation, fertiliser application and high stocking densities have affected their hydrology and water quality.

A wetland's hydrology is also affected by changes in its catchment. For example, urban expansion radically modifies catchment hydrology and has a significant effect on wetlands. This can make it difficult to establish how a wetland originally looked.

Changes to the wetland

Drying up

Drainage, including the deepening of nearby drains, is the main cause of wetlands drying up. If a wetland becomes too dry, the number of wetland plants decreases and dry land plants take over, especially weeds. Peat soils also break down when they dry up and are exposed to the air.

Flooding

In contrast, wetlands that are artificially flooded may not give plants important seasonal variations that are clues for growth and flowering. Permanent flooding will reduce a wetland's health and diversity. For example, a wetland with year-round standing surface water offers a habitat that is very similar over large areas for a long period of time, resulting in dominance by only a few plant species.

Changes to the wetland's catchment

Wetlands are part of larger hydrological systems, which means their hydrology can change as a result of activities well beyond their surface boundaries – such as regional groundwater overuse.

In addition, removing a catchment's original forest cover for agricultural development alters rainfall run-off characteristics and inflows to wetlands. Flood protection programmes (such as stopbanks) stop the regular flooding of floodplain wetlands and further increase the impact on wetland hydrology.

Urban development has even greater effects through increases in 'impervious surfaces', such as roofs, driveways, roads, carparks and paved areas. Instead of soaking into the ground, rainfall (stormwater) rushes across these impervious surfaces and through a stormwater drain to the nearest stream or wetland. The increase in volume and the speed at which this water travels can increase flooding and erosion and, in some cases, lead to water scouring a channel through the wetland.

Rain, as it travels over – or runs off – impervious areas can also pick up toxic substances such as oil and sediment and wash them into a wetland. Sediment, although not toxic itself, can damage a wetland by causing it to silt up.

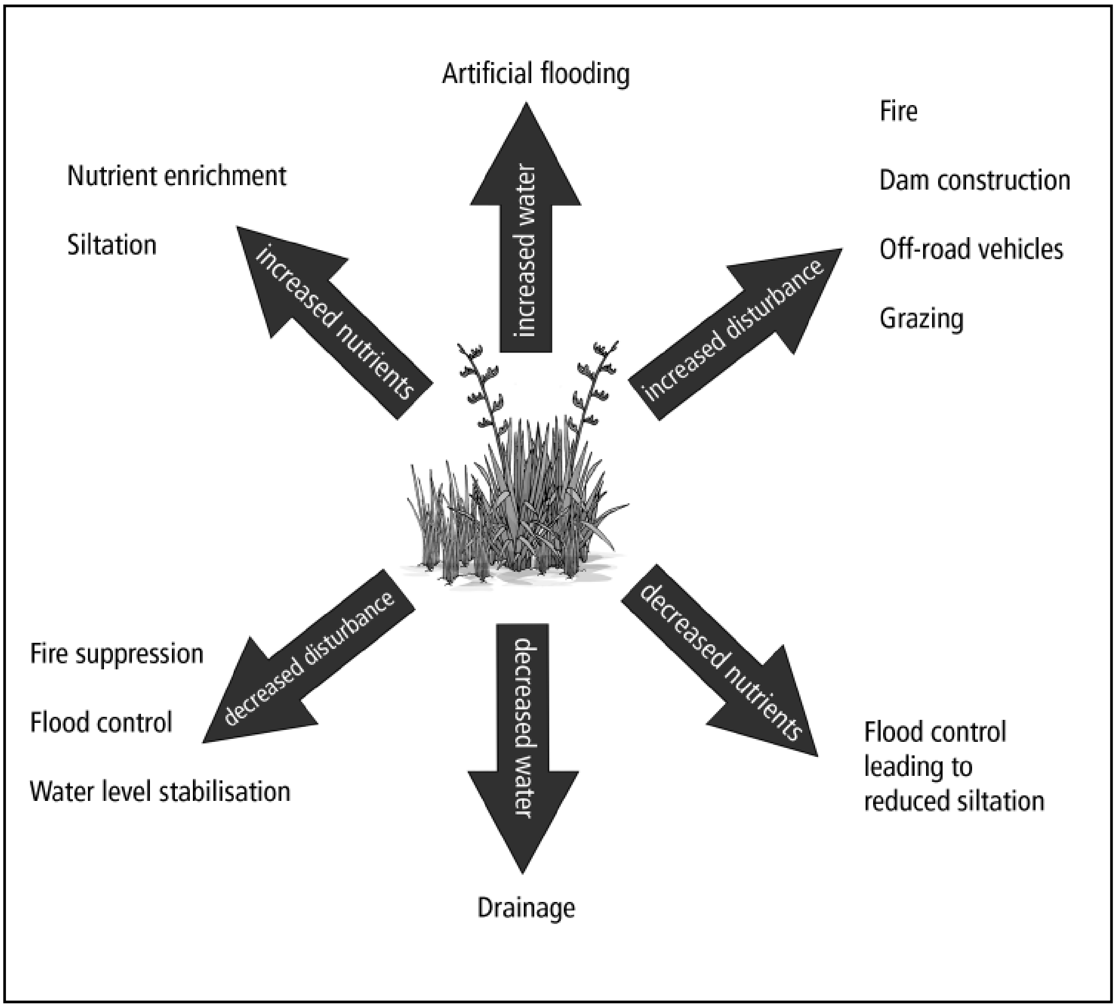

Figure 3: Human impacts on wetlands (after Keddy, PA 1983. Freshwater wetland human-induced changes: Indirect effects must also be considered. *Environmental Management 7:299-302)*

5. Restoring hydrology in wetlands – approaches and requirements

If you're planning to restore a wetland to its natural state, it's important to spend a year or two observing it and gathering information, and seeking advice and information from Greater Wellington or other experts. They will either have specialist skills or be able to direct you to someone who has (see Section 8 for more information). Some organisations also have assistance programmes.

If you're aiming to restore a wetland, keep in mind that most natural wetlands in New Zealand are dominated by waterlogged soils and not areas of open water. The creation of open-water ponds in a wetland is one form of wetland management but it doesn't necessarily equate to wetland restoration. 'Restoration' may be as simple as fencing the wetland and leaving it to do its own thing.

What is restoration?

'Restoration' is the return of a damaged wetland as close as possible to its original condition.

The aim is to return the wetland to a healthy, self-sustaining condition, dominated by native plants and animals. It may not be possible to return a wetland completely to its natural condition.

Determining the natural state of a wetland

The potential for successful restoration depends on how far the wetland has been altered from its natural condition. To find this out, you need information about historical changes in the wetland and its wider catchment. Very few wetlands are in a near-natural state, so it may be difficult to get a good idea of how it might once have looked.

Historical information can be sourced from:

- old maps
- historical photographs, especially aerial photographs that also provide information on the wider catchment
- people who have lived in the area for a long time
- local historical societies and museums.

It's also useful to identify the human influences and land management practices that may be affecting the wetland, such as:

- drainage control measures (ditches, drains, channels, water races, deepened streams, stopbanks) in and around the wetland
- structures designed to manage water levels in the wetland artificially (e.g. weirs, dams)
- vegetation changes in the catchment (e.g. bush removal to create pasture)
- intensive agricultural practices in the upstream catchment
- heavy grazing in the wetland

- artificially created ponds
- roads, built-up tracks and culverts in and around the wetland
- burning, vegetation clearance or chemical use in or near the wetland
- water takes (surface water or groundwater) in the wetland's catchment (e.g. for urban water supply)
- urban development in the catchment.

Any major change in the types of plants in a wetland can indicate that the water regime has been modified. For example, the invasion of a wetland by dry land species (such as gorse, broom, pasture grasses, kanuka and mahoe) indicates the wetland is drying up.

Monitoring these species can be an effective substitute for direct hydrological monitoring. The *Handbook for Monitoring Wetland Condition* (see Section 9) has more information on monitoring vegetation changes.

Setting restoration goals

After information gathering, the next important stage of a wetland management or restoration plan involves defining the goals clearly.

They may be[5]:

- reducing flooding
- improving water quality
- increasing wildlife or fisheries resources
- re-establishing a natural wetland ecosystem to enhance native biodiversity.

The landscaping, hydrological and planting actions for these goals are very different. For example, if you want to attract waterfowl you'll need plenty of open water with vegetation on the edges and islands for breeding. Fish will need good access in and out of the wetland and plenty of vegetation in the water.

If your goal is to enhance native biodiversity, ideally you'll be able to find a 'reference site' to help you set targets – that is, a comparable local site that is as close to pristine and unmodified as possible[6]. In reality however, there are few unmodified sites left, so you may have to rely on historical information.

Your restoration plan should include a clear statement of what you expect to achieve from management actions. For example, you could plan to:

- poison grey willows to increase light penetration and open space and allow native species in the seed bank, such as purei and rautahi (both *Carex* species) to germinate and recover
- block drains to achieve permanent soil saturation and to kill weeds from 80% of the wetland area
- fence the wetland to stop grazing and allow native species to germinate and recover.

[5] Based on Sorrell et al. (2004).

[6] Sorrell et al. (2004).

If you’re part of a group planning a project, it’s useful to think about your vision as a group and develop your goals together. Ask your group what they want the wetland to be like in the future. Write everyone’s ideas on a large piece of paper and check how they’re different or similar. Pull together the main ideas to create a vision with which everyone is happy – for example, “Heta’s wetland is a healthy haven for native birds, fish and wetland plants”.

Ask your group what they need to achieve their vision. Get everyone to write ideas on sticky notes and group similar ideas together to develop goal statements. Also note what might get in the way of achieving the vision to help identify any critical action areas.

For more information on group planning, see the Department of Conservation booklet From Seed to Success – Tool Kit for Community Conservation Projects at www.doc.govt.nz under community, sponsorship and partnerships.

Restoration at different scales

You can approach wetland restoration at different scales, depending on your goals and resources. The three main scales are:

1. the local scale – the wetland and its immediate surroundings
2. the catchment scale – the wetland and its catchment
3. the regional scale – the wetland, its catchment and nearby catchments.

Local-scale changes are the easiest to undertake as they are more likely to be under your control.

General approaches

The techniques for restoration tend to fall into three categories, depending on your restoration goal[7]

1. restoring and managing the wetland’s hydrology
2. controlling or removing pollution entering the wetland
3. restoring native plant and animal communities (generally by removing stock and undertaking pest and weed control, but natural water levels will also help address weed problems).

Local landowners and resource consents

Restoring natural water levels and fluctuations to a wetland may affect water levels on neighbouring land, both upstream and downstream.

Sometimes such changes won’t be compatible with the neighbouring land use, so its crucial to discuss your plans with your neighbours and reach an outcome that everyone can live with. Agreeing on a hydrological regime that suits everyone will depend on open dialogue, respect and a mutual understanding between wetland managers and neighbouring landowners.

[7] NRC (1992)

Daming and diverting water, whether over or under the ground, requires a resource consent unless it is specifically allowed by a rule in a regional plan. Greater Wellington's Regional Freshwater Plan has rules that allow diversion of water from water races, farm drains or groundwater, provided it does not cause flooding or lower water levels in rivers, lakes and wetlands. Before taking any actions that will dam or divert water, read the rules on www.gw.govt.nz/regionalrules or contact the Consents Help Desk on 0800 496 734.

6. The restoration process

Restoring wetland hydrology is a relatively new concept in New Zealand. This section provides some general guidance on restoration techniques that we hope will be expanded as new examples develop around the country.

Adaptive management is the key to a successful restoration, bearing in mind that wetlands are complex and dynamic ecosystems about which we have only a limited understanding. Your project should be supported by ongoing monitoring, and management needs to be adaptable to take changes into account and respond accordingly.

Assess the wetland hydrology

Successful restoration usually involves an assessment of the wetland's hydrology.

This assessment may need to be detailed and accurate and at other times it may need only basic information.

Assessing the current wetland hydrology will:

- help you understand the water regime and what drives it
- help you recognise your wetland type (see Appendix 1)
- help you recognise when (and if) intervention and restoration action are necessary
- provide a baseline for tracking the wetland's health, including assessing the effects of human activity in and around it.

Remember the restoration principles

1. Water levels should fluctuate – but not too much

Where possible, restoration should provide for the natural seasonal variability in water levels, so that you provide for the maximum diversity in re-establishing plant species[8].

Beware of stable water levels – those that feature in many restoration projects with areas of open water are unnatural. They can result in dry land plant communities above the water line and aquatic plant communities below the water line, with very limited habitat in the zone where water would normally fluctuate and support a wide range of plants and animals. Conversely, rapid or extreme unnatural fluctuations (more than 10 centimetres) in freshwater wetlands over a short time (from hours to a few weeks) mean nothing at all can grow in the zone where water levels fluctuate[9].

2. Minimise structures and intervention

Overall, the less intervention you use to achieve your restoration goals, the better. Structures such as weirs and flap gates can be barriers to fish passage and should only be used as a last resort. Ideally, your wetland should maintain itself over time. Create the right environment and let nature do most of the work.

[8] Sorrell et al. (2004) in *Freshwaters of New Zealand.*

[9] Sorrell et al. (2004) in *Freshwaters of New Zealand.*

3. Think about nutrient impacts

It's also important to think about nutrients when restoring hydrology – if you redirect nutrient-rich water into a wetland area, it may have significant and unexpected effects on your overall site. Wetlands with very high nutrient levels are less diverse, usually dominated by one or two highly competitive, often exotic, plants.

4. Give the systems time

Be aware that restoration is a long-term project. It may take several years for your wetland to recover.

Choose your restoration method

Blocking drains

Many wetlands in depressions or on flat land have been drained. You can restore this relatively inexpensively by plugging drainage ditches with either soil dams or artificial weirs.

You can often find the best material for plugging drains right beside the drain – it's the soil that was dug out of the drain in the first place. Other soil sources may be nearby, but they should be roughly the same type of soil as that removed from the drain site.

If tiles have been installed to collect and channel water into drains, they can be plugged with a low-permeability, clay-like soil. In some cases, drains will naturally 'silt up' and you won't need to intervene. Monitoring the hydrology will help you decide.

Case study 1: Wetland restoration at Bullock Creek, Westland

The Department of Conservation (DoC) is working with NIWA (the National Institute of Water and Atmospheric Research) and Landcare Research on a wetland restoration project at Bullock Creek, in an area of former farmland in Paparoa National Park.

The hydrological regime is critically important for this wetland. Monitoring at the site has shown that, despite the West Coast's dramatic rainfall and quickly flooding topography, the main factors controlling vegetation patterns are the gradual drying of soils between floods and the impact of drains.

To test whether exotic weeds can be discouraged and natives encouraged, some drains have been closed and scientists have been measuring how this has affected vegetation in the wetland. Results to date indicate that the cover of weeds has been greatly reduced in the areas where drains have been closed. This is because native species at this site are more flood-tolerant than the introduced pastoral grasses and can cope with less oxygen in the soil.[10]

[10] Sorrell BK, Partridge TR, Clarkson BR, Jackson RJ, Chagué-Goff C, Ekanayake J, Payne J, Gerbeaux P and Grainger NPJ (submitted 2004). Soil environmental and vegetation responses to hydrological restoration in a partially drained polje fen in New Zealand. *Wetlands Ecology and Management.*

Case study 2: Restoration of Dunearn peat bog, Southland

Deep internal drains and an external ring drain have extensively modified the Dunearn peat bog on the Southland plains. Because it is ecologically significant and has good restoration potential, DoC bought the bog through the Nature Heritage Fund in February 2003.

In June 2003, DoC plugged the three main internal drains with sods of peat to restore wetland hydrology. DoC and Environment Southland have been monitoring vegetation, peat and the water regime to see how drain plugging makes a difference. Environment Southland installed dip wells in February 2003 to monitor changes in the groundwater regime. DoC has established vegetation plots for annual monitoring. Photos are also being used to record change over time.

Prior to restoration, the bog had lower water levels – peat was breaking down and the uncommon jointed rush, *Empodisma minus*, was dying. Since the drains were plugged, the groundwater and peat levels appear to have increased, either as a direct response or indirectly through high rainfall. Ongoing monitoring of changes in the water table, potential vegetation and peat recovery will contribute valuable knowledge to the management of Southland's remaining peat bog systems.[11]

Installing water-level controls

Some wetlands may be drying up because of changes in their catchment (for example, the taking of groundwater). This makes restoration difficult.

You may be able to raise water-levels using weirs, stopbanks, direct pumping or siphoning, or a combination of these techniques. Talk with all potentially affected parties and seek advice about the likely effects of your plans on neighbouring land. You may need help from an engineer and an ecologist to design and build effective water level control structures and you're likely to need a resource consent from Greater Wellington. Before taking any actions that will dam or divert water, read the rules on www.gw.govt.nz/regionalrules or contact the Consents Help Desk on 0800 496 734.

Some water control structures, such as weirs, valves and one-way flap gates, can be used to hold water in depressions and manage flow. These structures on the inlets and outlets can allow many natural hydrological patterns to be mimicked, e.g. seasonal fluctuations. Again, talk with all potentially affected parties and seek advice from an engineer and an ecologist about the likely effects of your plans. It's also important to think about how fish and eels are able to move in and out of your wetland, especially if you're removing or building water-level-control structures. Talk to Greater Wellington or DoC about how to best provide fish passage.

[11] White M and McNutt K (2003) *Dunearn Peat Bog: Restoration and Monitoring.* SRC Publication No 2003-12. Environment Southland and Department of Conservation, Invercargill.

Pumping water

Active pumps and siphoning systems should be a last resort because they are expensive to install and operate. However, they can be the only way to move enough water into the site to achieve real ecological change. Before starting down this track, you'll need to establish the desired water regime, how this will change your site and its feasibility in resources and time. Measuring the hydrology of a reference site will help give you an idea of the water regime you should aim for.

Controlling pollution

If your wetland is affected by water pollution from agricultural or urban run-off, you may want to take steps to control or mitigate it. Fencing the wetland is a good first step to improving wetland water quality. This will also allow wetland plants to regenerate (see section below), although you'll need to keep an eye out for weeds that grazing may have suppressed.

If you can't control the water pollution source, you may want to consider planting a buffer of native plants around the wetland edge. This will help catch sediment and nutrients before they enter the wetland or neighbouring streams. Dense planting with one productive species can be the best option for pollution control. See Sections 8 and 9 for details on where to find more information on controlling pollution.

Bringing back native plants and animals

While this guide focuses on wetland hydrology, there are several good sources of information on restoring plants and animals in wetlands. Contact Greater Wellington Regional Council for a copy of the booklet *A Beginner's Guide to Wetland Restoration,* which covers planting, weed and pest control.

Freshwaters of New Zealand also contains a chapter on wetland restoration. See Section 9 for more information.

7. Monitoring the wetland hydrology

Decide what to monitor

Your wetland hydrology monitoring programme doesn't have to be complex or comprehensive.

Measuring water table levels fortnightly or monthly over a year or two will give you a picture of what's happening under the ground.

Simple things you may like to monitor include:

- water levels – the surface water depth and water table depth
- the stream flow into and out of the wetland
- rainfall.

Measuring water table levels fortnightly or monthly over a year or two will give you a picture of what's happening under the ground. Note you may want to measure them more often during times of flood or drought.

It's also useful to record regularly your general observations about water in the wetland, and take photographs. You can record information on:

- the extent of water coverage, especially after flooding (use pegs to mark levels during different floods)
- the types of stream inflows (where applicable) e.g. one defined channel or many channels
- any ecological observations (such as what birds are seen, when plants have flowered and any plants that appear to be dying).

You can also gain a good idea of the hydrology using local knowledge of the wetland, such as how often it floods and the extent and depth of water.

The detailed *Handbook for Monitoring Wetland Condition*, published by the Ministry for the Environment (2004) is a useful resource for designing a monitoring strategy for your wetland.

Keep records

Whatever you decide to monitor, keep all your information together in a journal, such as a bound exercise book or diary. Record the dates, measurements and any other observations. Make your records descriptive.

Take photographs

Photographs are an extremely valuable addition to your monitoring journal. Create 'photo points' or include a marker (such as a tree) in a panorama to help get the same shot each time. Date and store the photographs in an album.

Record the extent of water

It's useful to know the extent of water in your wetland during wet and dry periods. After a flood you can mark it out with pegs. This will give a good idea of where the wetland boundary is if an area has been grazed, and will help you decide where to put any fences.

Measure the water levels

Aim to take water measurements fortnightly, or weekly if you can. After lots of rain, it's a good idea to take measurements daily. Depending on your budget, you may want to consider buying an electronic water level recorder, which costs about $250.

Measuring water levels above ground (surface water)

The best way to measure the water depth is to install a 'staff gauge' (see Figure 4, Figure 5 and the box below). A staff gauge has centimetre intervals marked on it and is stuck to a stake in the wetland. If you can't get a staff gauge, you can improvise – use a wooden post or marks on a tree. You may need gumboots or waders to get close enough to read your staff gauge.

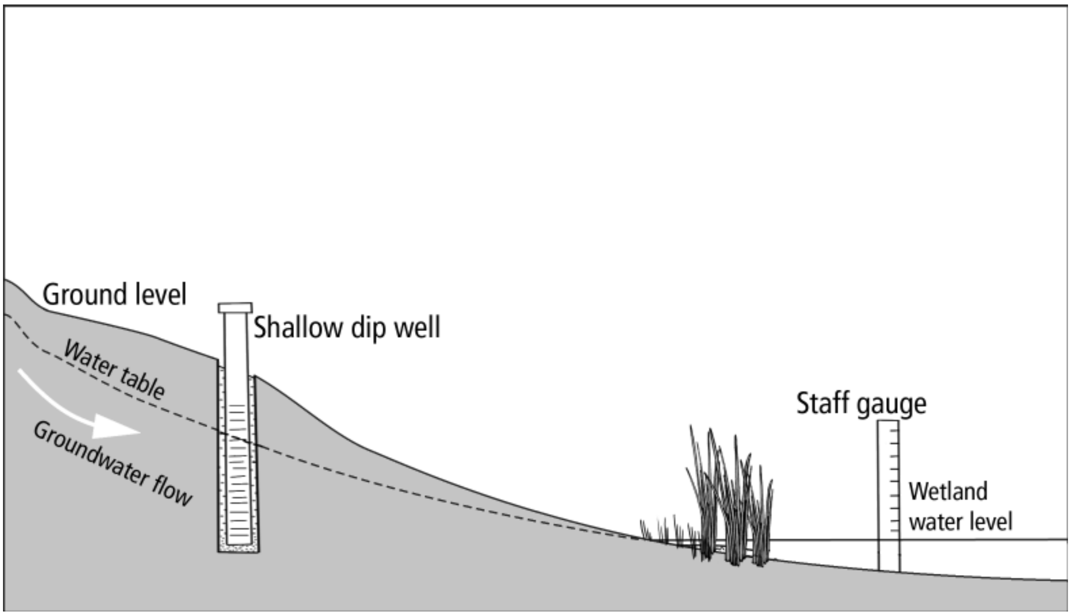

Figure 4: A wetland dip well and staff gauge

Figure 5: Staff gauges are a simple way to measure water level in wetlands with open water.

Installing a staff gauge

Drive a wooden or metal stake firmly into the soil. Remember there may be a lot of ‘ooze’ in your wetland, so you may need a long stake.

Attach a gauge plate (a broad metal or plastic ruler with clearly visible measurements) securely to the marker so it can’t move. The gauge plate should sit at the base of any soft ooze and face the shore where you’ll make the readings.

Measuring the water level below ground (groundwater)

Surface water can disappear from the wetland during dry times, but the water table will probably remain close to the ground surface, maintaining wet soils. It’s useful to continue monitoring the depth to the water table using a simple monitoring well (or ‘dip well’) – see Figure 4 and the box below.

Building a low-cost groundwater monitoring well

- Drill a hole about 100mm in diameter to a 1-2m depth with a soil auger or a post-hole digger, or by hand.
- To get a good indication of the water table depth, dig the hole during the driest part of the year. Dig about 0.5-1m deeper than the water level in the open hole.
- Put about 5cm of free-draining gravel in the base of the hole.
- Get a length of pipe (a 50mm diameter PVC pipe works well) that is long enough to protrude about 1m above ground level.
- Cut narrow slots in the pipe with a hacksaw to let the groundwater in freely. Block the end with a cap to stop it filling up with gravel and soil.
- Fill the gap between the hole and the pipe with gravel or coarse sand – make sure whatever you use is too big to fit through the slots you’ve cut in the pipe.
- You can cement the pipe at the ground surface to secure it.
- Flush the pipe by making a ‘bailer’ – a weighted elongated container attached to a string – that can fit into the pipe, sink below the water level and fill with water. The bailer can be made from a smaller diameter short length of pipe blocked at one end. Use this several times to flush the pipe. After bailing, wait overnight (at least) before you take a water measurement.

To measure the water depth, lower a weighted tape measure until it touches the water surface – either use a torch or listen carefully for the ‘plonk’ as the weight hits the water. Also measure and record the distance between the top of the pipe and the water surface. To calculate the depth of the water table below ground level, subtract the distance from the top of the pipe to the ground from the distance from the top of the pipe to the water level. Record both measurements in your monitoring journal.

To measure the water depth, lower a weighted tape measure until it touches the water surface.

For example, in Figure 6 the groundwater level is calculated as:

- distance from top of pipe to water = 130cm (a)
- distance from top of pipe to ground = 90cm (b)
- distance from ground level to water = (a) – (b) = 130cm – 90cm = 40cm

That is, the water level is 40cm below the ground.

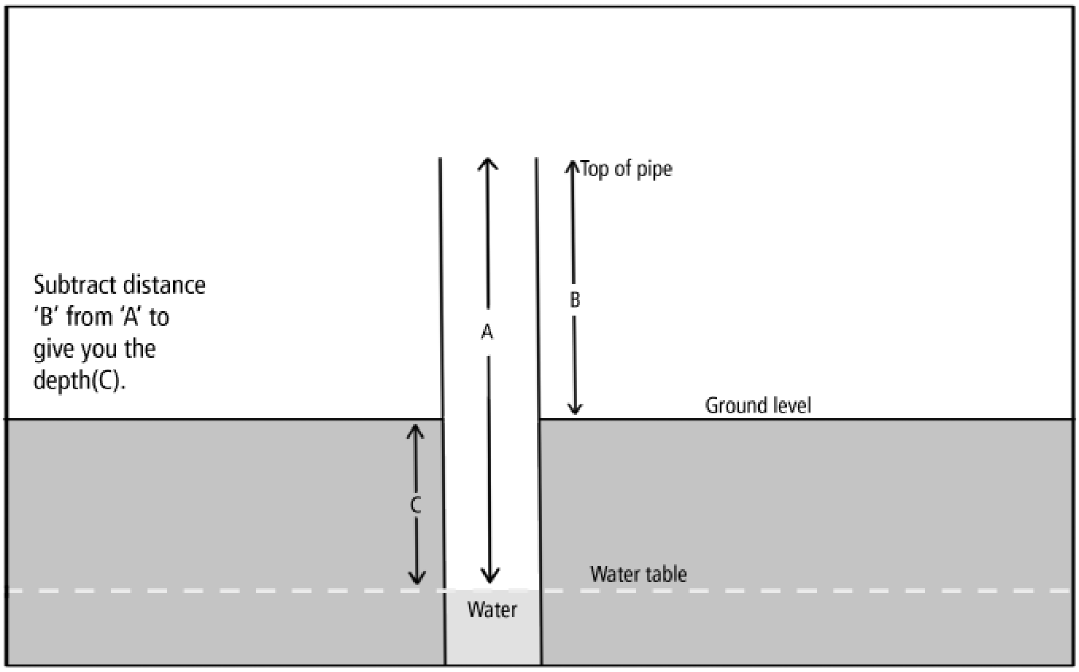

Figure 6: Calculating the underground water level (after Brock, M et al, 2000. *Does Your Wetland Flood and Dry? Water Regime and Wetland Plants.* LWRRDC and UNE, NSW, Australia

Measure the stream flow

Stream flow can make an important contribution to a wetland's inflows and outflows, so it's useful to know, even if it is a little more complicated to calculate than water levels (see below).

Stream flow is easiest to measure where the stream is straight or where you can build a measuring weir. Any structure constructed in, on or over the bed of a river requires a resource consent unless it is specifically allowed by a rule in a regional plan. Greater Wellington's Regional Freshwater Plan has rules that allow the construction of weirs and dams in intermittently flowing streams, subject to complying with conditions in the rules. Before installing any structure in the bed of a river (this includes streams and modified watercourses), read the rules on www.gw.govt.nz / regionalrules or contact the Consents Help Desk on 0800 496 734.

Measuring stream flow

When measuring stream flow, choose a straight part of the stream that is confined to a single straight channel.

Stream flow = cross-sectional area of the stream x average speed of flow

The cross-sectional area of the stream channel is the width of the stream, multiplied by the average depth of the water. You can estimate the average water depth by measuring the depth at several points evenly distributed across the stream, and then taking the average of those measurements.

Work out the average speed of the stream flow by using hand-held velocity meters, or more simply the ‘floating-orange technique’ where an orange is timed as it floats downstream (oranges, being 90% water, float just below the surface). Make sure you use the same measurement units for the cross-sectional area and the flow velocity measurements.

Here’s an example of a stream flow calculation:

- the cross section area of water in the channel is 1.2m wide by 0.3m deep = 0.36m^2
- the average flow velocity using the floating orange technique is 10m in 50 seconds (10 divided by 50) = 0.2m per second
- the stream flow is therefore 0.36 x 0.2 = 0.072m^3 per second, or 6,220m^3 per day (there are 86,400 seconds in a day).

Record the rainfall

A rain gauge can provide valuable site-specific data for assessing the wetland water regime. It can be read weekly, or even daily, during periods of heavy rain.

A farm supply store is likely to have standard rain gauges for sale. Mount yours in an open space within or near the wetland and away from any sheltering or turbulence effects caused by vegetation.

Interpret the data

A computer database is useful for processing and analysing data. You can plot water level measurements on graphs, using different lines for different staff gauges or groundwater monitoring wells. The graphs will illustrate the wetland hydrological regime and give you an idea of the patterns and processes that give the wetland its unique characteristics. When characterising the water regime, questions you could ask are:

- Is the pattern of water presence and depth related to season?
- Do the maximum depth and spread of surface water vary from year to year?
- Does the timing of flooding vary from year to year and how often does it flood?
- How long does surface water stay present, and how quickly does the water level respond after rainfall?

- Is the amount of surface water flowing into the wetland about equal to the amount of water flowing out?
- Does the wetland dry out, and for how long?
- How does the groundwater level fluctuate, is it seasonal, does it respond to rainfall events?
- How do these observations tie in with your observations of the wetland habitat?

By plotting and tracking the changes in the water regime and plant habitats over time, you can interpret the changes you have observed. Greater Wellington staff may be able to help with this interpretation.

The information will help you decide if your project to restore a more natural water regime is working, or if further management is needed.

Figure 7 is an example of a water regime from Queen Elizabeth Park, Kapiti Coast. You can see the pattern and timing of flooding and drying. The wetland is ephemeral, with the water level generally only above the surface in spring (the wettest time of year in Kapiti).

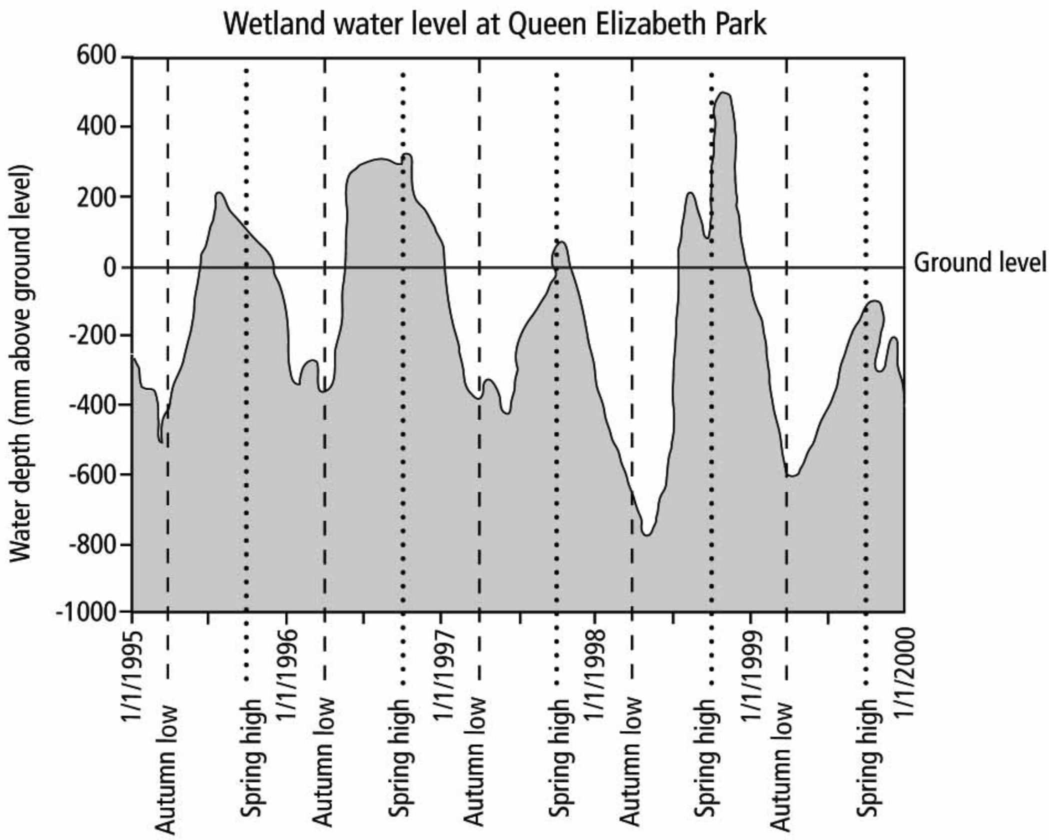

Figure 7: The timing of flooding and drying of a wetland in Queen Elizabeth Park, Kapiti Coast.

8. Finding out more

If you'd like to know more about any of the subjects covered in this guide, see the information sources below.

Remember to ask for help if you need it. Wetland management experience is increasing in our community – it's just a matter of asking around.

Greater Wellington Regional Council

Wetland Advisory Service. Greater Wellington provides advice and assistance for landowners restoring wetlands. Information about Greater Wellington's wetland programme is available at www.gw.govt.nz / wetlands or by calling 04 384 5708 or 0800 496 734, or email wetlands@gw.govt.nz.

Resource consents. Your wetland restoration may involve activities that require a resource consent, for example, to dam or divert water, or place a structure in a river. Information about resource consent requirements is available at www.gw.govt.nz / regionalrules or by calling 04 384 5708 or 0800 496 734, or email regionalplanenquiries@gw.govt.nz. You may also need to contact your local district or city council.

Department of Conservation

The Department of Conservation may be able to advise you on how to identify, maintain, legally protect and enhance wetlands. Contact your local office or visit www.doc.govt.nz.

National Wetland Trust

The National Wetland Trust seeks to increase New Zealanders' appreciation of wetlands and their values. To find out more about its work, check out www.wetlandtrust.org.nz

New Zealand Landcare Trust

The New Zealand Landcare Trust helps with community group projects and can sometimes provide funding. Visit www.landcare.org.nz or phone 0508 526 322.

Fish and Game New Zealand

Fish and Game New Zealand can provide specialist advice and support for landowners seeking to enhance wetlands or develop farm ponds for game bird habitat. Funding may be available. Find out more at www.fishandgame.org.nz or phone their Wellington office on 04 4776118.

Crown Research Institutes

Landcare Research (Manaaki whenua) and NIWA (the National Institute of Water and Atmospheric Research) carry out scientific research into how wetlands function and on science-based methods for restoring wetlands. Find out more about how hydrology controls the habitat and use of wetlands by plants and animals, and what this means for restoration, at www.landcareresearch.co.nz and www.niwa.co.nz.

QEII National Trust

The QEII National Trust helps private landowners protect natural areas such as wetlands, by using covenants. For more information, visit www.qe2.org.nz or phone 0508 732 878.

New Zealand Ecological Restoration Network (NZERN)

NZERN is a non-profit, community-driven organisation dedicated to sharing knowledge and experiences about native habitat protection, management and ecological restoration. Check out www.bush.org.nz.

9. Further reading

- *Freshwaters of New Zealand* (2004) Harding JS, Mosley MP, Pearson CP and Sorrell BK (Editors), New Zealand Hydrological and Limnological Societies.

  This book contains useful chapters on wetland restoration and wetland hydrology.

- *Handbook for Monitoring Wetland Condition* (2003, revised edition 2004) Clarkson BR, Sorrell BK, Reeves PN, Champion PD, Partridge TR and Clarkson BD, A Ministry for the Environment Sustainable Management Fund Project.

  Electronic copies of this publication are available at through the National Wetland Trust's publications section on their website www.wetlandtrust.org.nz or at www.smf.govt.results/5015_handbook_2004.pdf

- *A beginner's guide to wetland restoration* (2003) Greater Wellington Regional Council.

  This easy to read booklet describes wetlands and why they are important, what lives in them and the general steps to follow to restore a wetland. You can get a copy by contacting Greater Wellington on 04 384 5708 or email publications@gw.govt.nz or read it on www.gw.govt.nz.

- *Wetland Types in New Zealand* (2004) Johnson P and Gerbeaux P, Coordinated Monitoring of New Zealand Wetlands.

  Classifying wetlands helps in recognising wetland types, so that each can be better understood, managed and monitored. This book describes and illustrates how different wetland types (e.g. swamp, bog, marsh) can be recognised and named.

- *Wetlands* (2000) Mitsch WJ and Gosselink JG.

  Wetlands is the international textbook on wetlands. It has a good wetland hydrology chapter and is more commonly found in university and other specialist libraries than local libraries.

Appendix 1: Types of freshwater wetland

Understanding where a wetland gets its water from, and how much and how often, is part of the key to working out what type of wetland it is. If you're planning to restore your wetland, this information will be important in guiding your restoration actions.

Freshwater wetlands in New Zealand can be grouped into different wetland classes based on their substrate, water source, nutrient status and pH[12]:

- **Ephemeral wetland**: a wetland found in closed depressions without a surface outlet, with highly varied water levels owing to seasonal variations in rainfall. This wetland is fed by groundwater or nearby surface water. Water flow is slow to nil and nutrient levels are moderate. Vegetation tends to be turf and sward, and sometimes also rushland and scrub.
- **Bog**: a peat wetland that gets its water entirely from rainfall. Bogs have very low nutrient levels and are acidic. The water table is generally close to the ground surface and relatively constant, with almost no water flow. Bogs support a wide range of plants, including mosses, lichens, cushion plants, sedges, grasses, ferns, shrubs and trees. New Zealand bogs are famous for their restiad rushes, especially wire rush, which is often the dominant plant species and forms their peat.
- **Fen**: a wetland with either peaty or mineral soil[13], in which rainfall, groundwater and surface inflows can all be important water and nutrient sources. Fens have poor to moderate nutrient levels. The water table is generally close to the surface and water flow is slow to moderate. Fens often support the most diverse plant species of all wetlands, including sedges, ferns, tall herbs, tussock grasses, scrub and many other plants.
- **Marsh**: a mainly mineral wetland, fed by groundwater or surface water of slow to moderate flow. Water levels may fluctuate markedly and the water table is usually below the surface. Standing or slowly moving water periodically inundates marshes. They have moderate to high nutrient levels. Marsh vegetation is often rushland, grassland, sedgeland or herbfield. Tall harakeke (flax), raupo and tussock sedges often dominate marshes. They are prone to weed invasion.
- **Swamp**: a wetland where most of the water comes from groundwater seepage or surface run-off (e.g. streams), carrying dissolved nutrients and often suspended sediment. Swamps usually have a combination of mineral and peat substrates and permanently wet channels with gentle flow. They are relatively rich in nutrients and the water table is usually permanently above at least some of the ground surface. Swamps support sedges, rushes, reeds, flax, tall herbs, scrub and forest. They are prone to weed invasion.

[12] Johnson and Gerbeaux, 2004.

[13] Peat soils are formed from the remains of plant material that has built up over long periods of time in wet conditions where a lack of oxygen prevents the rapid breakdown of material. Mineral soils contain few decomposing plants; instead they are made up of clay, sand, or silt.

- **Seepage**: a wetland on a slope where water percolates to the soil surface, but with less flow than a spring or stream. Seepages are usually located where groundwater diffuses to the surface – they are sites of active water movement. Seepage vegetation is usually low, such as moss, cushion or sedges, but sometimes includes scrub or forest.
- **Shallow water**: areas of shallow water generally less than about two metres deep on the margins of streams, lakes and rivers. Emergent plants that grow in shallow water include lake club rush and bamboo spike rush.
- **Pakihi and gumland**: areas with mature or skeletal soils of very low fertility – wholly mineral or sometimes with peat. They tend to be rain-fed with a poor ability to transport water. They are frequently saturated but seasonally dry. Pakihi and gumland wetlands usually support heathland vegetation (shrubs with restiads, sedges and ferns).

Figure 8: Many of the wetlands on private land in New Zealand are swamps.

Water, air, earth and energy: elements in Greater Wellington's logo combine to create and sustain life. Greater Wellington promotes **Quality for Life** by ensuring our environment is protected while meeting the economic, cultural and social needs of the community.

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