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Fig. 89 **Algalfield.** Middlemarch, Otago; a stream in open grassy country at a time when low summer flow and warm temperature encourage rampant growth of filamentous green algae: algalfield, shallow water; riverine.

2.9.2 Examples of aquatic plant growth habit

The following illustrations show how the growth habit of aquatic plants, and where they grow in relation to water surface level and substrate, can be used as additional descriptors for shallow-water habitats.

Fig. 90 **Emergent aquatic.** Hamilton Lake, Waikato; the shallow margins of a small lake of relatively stable water level where bottom-rooted plants are emergent, holding their foliage above water level. Emergent lake clubrush (*Schoenoplectus validus*) - yellow flag (*Iris pseudacorus*) reedland, shallow water; lacustrine.

Fig. 91 **Floating aquatic.** Near Lake Wairarapa, southern North Island; an ephemeral wetland where a long period of shallow ponding and moderate to high fertility have fostered a phase of dense herbs and grasses. The red vegetation is a dense pool-surface coating of free-floating plates of retoreto along with tiny green platelets of duckweed. Floating retoreto (*Azolla filiculoides*) - duckweed (*Lemna minor*) fernland, ephemeral wetland; palustrine.

Fig. 92 **Floating aquatic.** Taramakau Valley, Westland; a swamp pool with pondweed (*Potamogeton cheesemanii*), its floating, water-repellant leaves held upon stems which are bottom-rooted, even at depths of 2 m or more. Floating pondweed herbfield, shallow water; palustrine.

Fig. 93 **Rafted aquatic.** Waihola–Waipori wetlands, east Otago; a swamp channel bordered by giant sweetgrass (*Glyceria maxima*), rooted on, or closely beneath, the shore, but with buoyant stems and foliage extending as a raft several metres across the water. Rafted giant sweetgrass grassland, shallow water; palustrine.

Fig. 94 **Rafted aquatic.** Birchfield Swamp, near Westport, Buller; a raft of swamp vegetation that cannot be walked upon and hides the deep pool of water beneath. The pool surface has been covered first by a mass of stems and foliage, partly emergent, of milfoil (*Myriophyllum robustum*; centre foreground). This has been colonised by the perching pale-green tufts of the sedge *Isolepis prolifer*. Rafted milfoil herbfield, shallow water; palustrine.

Fig. 95 **Submerged aquatic.** Kaimai Range, Bay of Plenty; a stream crossing an upland forested plateau, where the gentle gradient, steady flow, and relatively low sediment load allow for the growth of dense clumps of charophyte algae that are attached to stream bed gravels and permanently submerged. Submerged charophyte algalfield, shallow water; riverine.

Fig. 96 **Submerged aquatic.** Garvie Mountains, northern Southland; a stream head emanating from alpine seepages, the stream rocks being vegetated with black aquatic lichens (*Verrucaria* spp.) and the shallow margins with mosses, a demonstration that many groups of non-vascular plants contribute to submerged aquatic communities. Submerged *Verrucaria* lichenfield, shallow water; riverine.

Fig. 97 **Submerged aquatic.** Tongariro River, Volcanic Plateau; a shallow stony pool of a river flood channel where the living matter is composed of attached films and suspended masses of iron bacteria which gain their energy by decomposition of organic matter and oxidation of iron. Submerged bacteriafield, shallow water; riverine.

THREE

Wetland patterns

Most wetlands are not uniform but contain several different plant communities. Two or more wetland classes may occur adjacent to one another, or one class may be contained within another. Some wetland complexes can even extend over more than one hydrosystem.

The spatial arrangement of wetland classes, vegetation structural classes, and also wetland forms will often produce a readily discernible pattern. A wetland can be described as being patterned when its features are arrayed in a repeated fashion, often most obvious on aerial photos. Sequences of several vegetation structural classes, such as sedgeland to scrub to forest, can usually be interpreted as lying along some environmental gradient, in this example probably from wet to drier ground. One clear type of pattern is the zonation of vegetation types, as can be seen beside a lake or estuary, where water fluctuation is obviously the strongest environmental influence. When several environmental factors are interacting, the patterns of spatial distribution can be more complicated, and will often provide a challenge for interpreting how they have arisen.

Because factors such as substrate type, wetness, and nutrient status vary along gradients, the resulting vegetation types seldom have distinct boundaries, but instead merge with each other, the transition zones being called ecotones. Patterns can occur at many scales. Many wetland types are difficult to delimit or map because they occur as patches or fingers among a matrix of dryland vegetation, or else as narrow elongated strips adjoining a lake or river.

Some examples of wetland pattern have already been illustrated in Section 2.6 on wetland forms. The six further examples in Sections 3.1 to 3.6 have been selected to demonstrate the following points:

- the relationship between hydrosystems, wetland classes, and vegetation structural classes;
- correlations between substrates, hydrology, and vegetation types;
- working examples of how wetland patterns can be interpreted;
- the usefulness of vertical and oblique aerial photos for revealing wetland features;
- means of portraying patterns: habitat and vegetation maps, diagrams, profile drawings;
- patterns at both a broad and a fine scale.

3.1 Hydrosystems and wetland classes on a coastal plain

Vertical aerial photos are an ideal way to perceive broad-scale patterns of landforms, wetland patterns, and vegetation. Bodies of water usually show dark, with different tones depending on water depth and clarity. Vegetation types can be discerned from their textures, tones, and colours, though the last two of these can vary between seasons. This example (Fig. 98) shows a coastal plain where wetlands have developed behind a series of former beach ridges, laid down over several thousands of years, as the coastline has prograded – moved seawards – in conjunction with a relative drop in sea level. Boundaries of hydrosystems and wetland classes are shown in Figs 99 and 100.

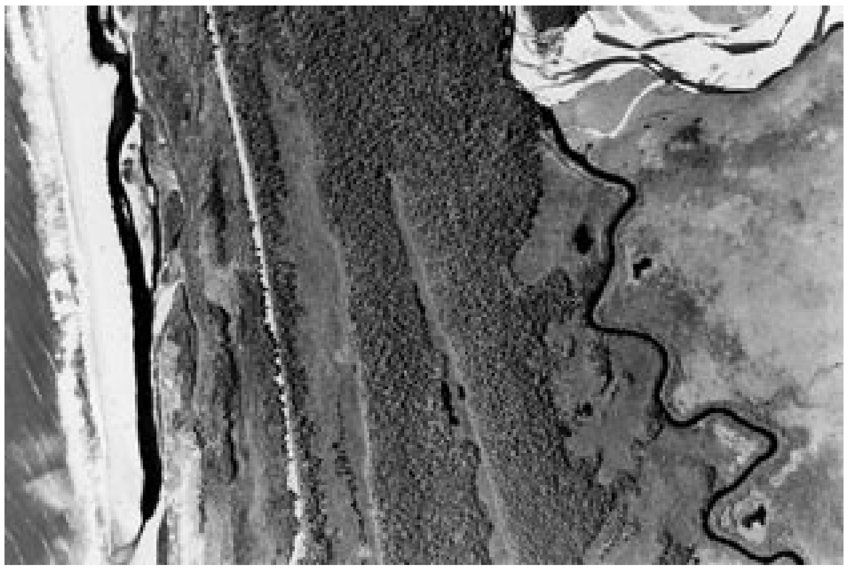

Fig. 98 This vertical aerial view embraces 2 × 1.5 km of a wetland complex on the coastal plain near Haast, south Westland. Beach ridges with podocarp forest have parallel intervening swales of bog. On the inland side (right) are swamps associated with the dark meanders of the Maori River. The pale area (top right) is the bed of the more flood-prone and sediment-loaded Waita River.

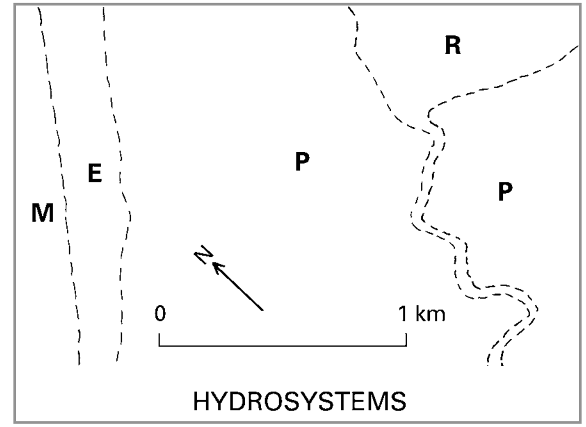

Fig. 99 Diagram relating to Fig. 98, showing the distribution of four hydrosystems: M = Marine; E = Estuarine; P = Palustrine; R = Riverine.

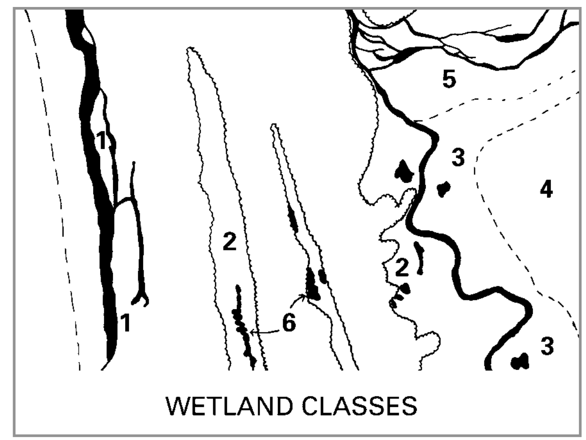

Fig. 100 Diagram relating to Fig. 98, showing the distribution of six wetland classes:
1. Saltmarsh on margins of river mouth lagoon;
2. Bog in swales between dune ridges;
3. Swamp infilling depression behind innermost dune ridge;
4. Fen on gentle slopes leading down to swamp;
5. Marsh on damp alluvium of river terraces;
6. Shallow water of bog and swamp pools, rivers, and coastal lagoon.

3.2 Linking hydrosystems to wetland classes and vegetation

Only a few wetland systems have a convenient nearby hill for an overview of the components. At the Wanganui River mouth in Westland the moraine hillock of Mt Oneone provides a panoramic view (Figs 101, 102, and 104) demonstrating hydrosystems, wetland classes, and structural classes.

Figs 101 and 102 The mouth of the Wanganui River and the gravel bar that encloses its small estuary. Note the patterns of water movement in the braided river and the various types of sediment in the estuary: a complexity that has its unseen counterparts in wetlands that are covered with vegetation.

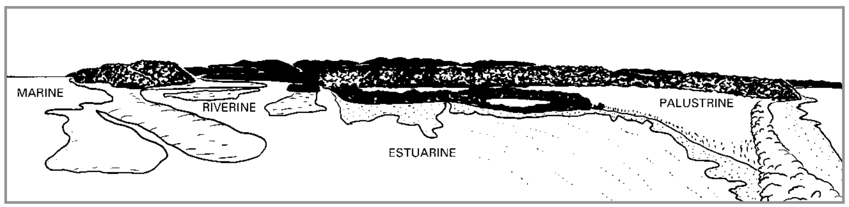

Fig. 103 Diagram showing the hydrosystems represented within Figs 101, 102, and 104.

Fig. 104 This palustrine wetland is called Doughboy Pakihi, but is best classified as fen plus swamp. It is a peat-filled hollow bounded by a coastal dune and the forested moraine ridge beyond.

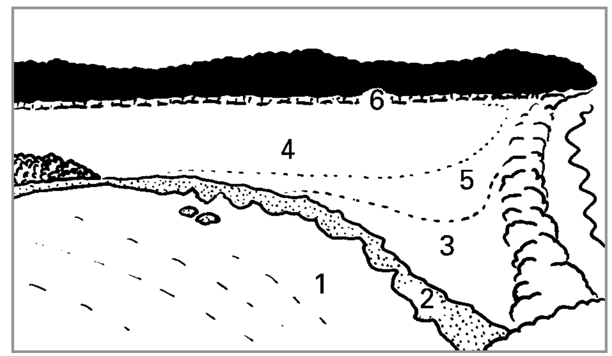

Fig. 105 Diagram relating to Fig. 104, showing the distribution of hydrosystems, wetland classes, and structural classes:
1. Estuarine mudflats;
2. Estuarine saltmarsh with zones of turf and rushland;
3. Palustrine swamp with flaxland;
4. Palustrine fen with sedgeland;
5. Palustrine fen with scrub (this zone recently burned);
6. Palustrine fen with treeland and forest.

3.3 Patterns on a river delta entering a lake

Most wetland patterns are a reflection not only of current environmental gradients, but also of landform genesis and human impacts. Lake Taupo is a huge, but relatively young lake, dating from the massive Taupo eruption of c. AD 186. Pushing into the south end of the lake, the Tongariro River has built a delta with coarse greywacke and pumice gravels on riverbank levees, and deposits of finer alluvium in the intervening hollows, where poor drainage is partly a result of ponding behind lake-shore storm-beach ridges.

Fig. 106 Wetlands on the delta of the Tongariro River, south end of Lake Taupo, with the town of Turangi just up-valley. There have been several human influences on this wetland system. Maori lived here, the Waitahanui Pa being situated on the left of the river's main mouth (left foreground). Farm development involved clearance of forest and scrub and attempts at drainage. Raising of Lake Taupo by c. 1 m in 1941 encouraged re-establishment of wetland vegetation. In the 1970s the Tokaanu Tailrace Canal was excavated through the wetland in right distance.

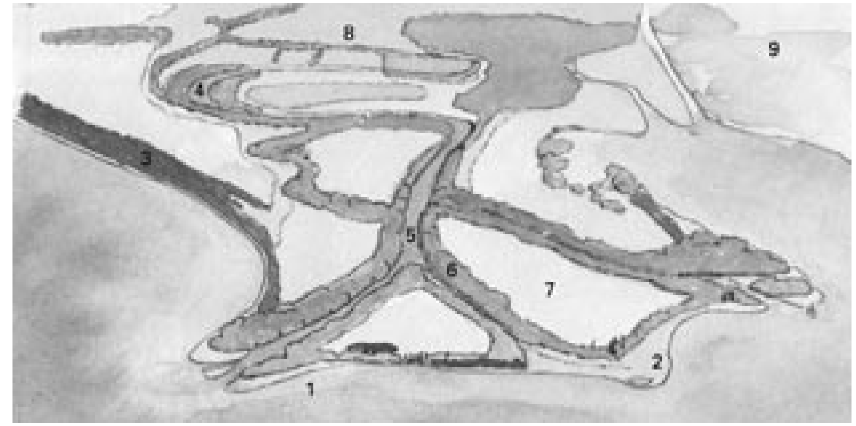

Fig. 107 Tongariro River delta: an interpretation relating to Fig. 106, showing the distribution of hydrosystems, wetland classes, landforms, structural classes, and vegetation:

1. Lacustrine shallow water, in bays and on delta shelf with submerged aquatic vegetation;
2. Lacustrine beach of bare pumice gravels, with turf and grassland;
3. Lacustrine storm beach with manuka scrub;
4. Riverine meander;
5. Riverine delta channel;
6. Riverine levee with crack willow forest;
7. Palustrine swamp with sedgeland, reedland, and flaxland;
8. Palustrine marsh with rushland and grassland;
9. Geothermal: localised fumaroles and hot pools near base of hill.

3.4 A dryland-to-wetland sequence on an alluvial plain

Patterns of wetland types are often caused by the way substrates of different-sized particles are deposited by gravity and along waterways. This example spans a sequence from dryland hillside habitats to progressively wetter wetlands. On a steep hillside large boulders and rocks tumble down to form well-drained talus slopes. During heavy rains, streams and rivers transport rocks and stones a certain distance down valley. Gravel, sand, and silt are carried a greater distance, to be deposited more slowly as substrates having progressively poorer drainage.

Fig. 108 Waiuna Lagoon, at Big Bay, south Westland, is a shallow, lowland lake that is being gradually infilled by the deltas of tributary rivers and streams.

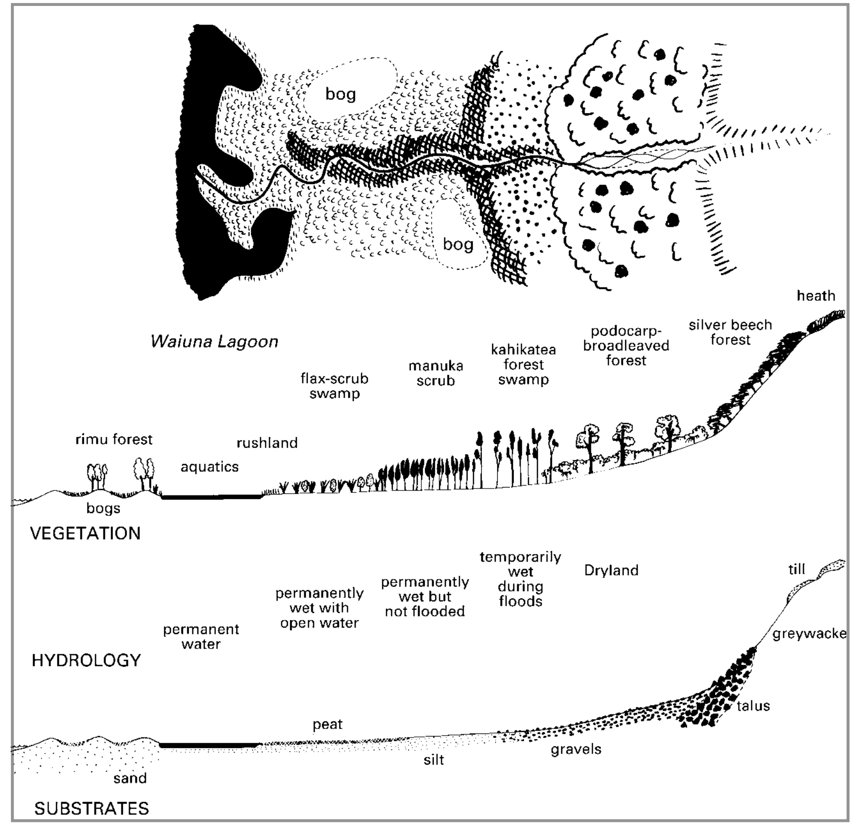

Fig. 109 Sketch map and profile diagrams of the alluvial plain and delta beside Waiuna Lagoon (see top right of Fig. 108). The gradient (right to left) of substrate materials and decreasing soil drainage is reflected in the sequence from forests to scrub swamp, bogs, marshes, then aquatic vegetation.

3.5 Zonation pattern on a lake shore

One of the more simple types of wetland pattern is a zonation, where a parallel sequence of wetland types arises in response to one dominant environmental influence. On lake shores strong zonation patterns are caused by water level fluctuation. Permanently aquatic zones are governed by the amount of light reaching different depths of water. Further upslope the zones relate to duration and frequency of submergence.

Fig. 110 Lacustrine shore zones, Lake Te Anau, Fiordland. This lake, glacial by origin, has a total fluctuation of 3.5 m. The turf zone (left) is under water about half the time. The zones of restiad rushes (centre), scrub, and forest (right) are submerged less often and for progressively shorter periods. At this site, stony shores of an exposed promontory meet the mobile gravels that belong to the end of a bay (foreground). These gravels display a stepwise set of low beach ridges, shaped by waves during successive storms through a period of falling lake level.

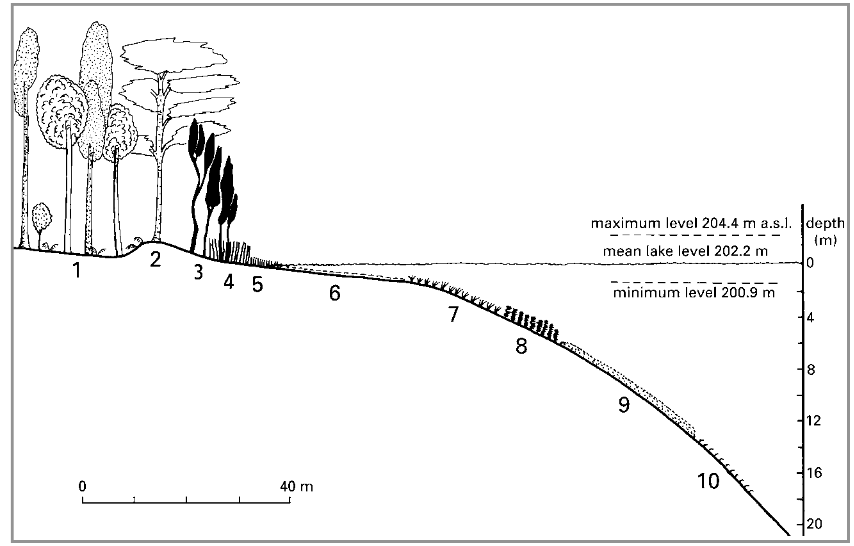

Fig. 111 Diagrammatic profile of a gentle, relatively sheltered shore at Lake Te Anau, Fiordland, showing the main vegetation zones in relation to fluctuating lake level:

1. Kahikatea (*Dacrycarpus dacrydioides*) - pokaka (*Elaeocarpus hookerianus*) forest swamp in poorly drained hollow behind storm ridge, sometimes ponded with floodwaters;
2. Beech (*Nothofagus*) forest on well-drained storm ridge, intolerant of inundation exceeding c. 50 days;
3. Manuka (*Leptospermum scoparium*) scrub marsh on silty gravels, tolerant of prolonged inundation by high lake levels;
4. Oioi (*Apodasmia similis*) restiad rush marsh;
5. *Carex gaudichaudiana* sedge marsh as a short sward;
6. Turf: several zones of turf marsh of different composition related to degrees of submergence and drying;
7. Aquatic herbfields: *Isoetes kirkii* beds and taller macrophytes (*Potamogeton* and *Myriophyllum* spp.), permanently submerged in the depth range of 2–8 m below mean lake level;
8. Canadian pondweed (*Elodea canadensis*) to 1.5 m tall, at 1–7 m depth;
9. Charophyte meadows: beds of *Chara* and *Nitella* spp. reaching 15 m depth;
10. Bryophytes: sparse mosses and liverworts to 17 m depth.

3.6 Pattern in a fiord-head marsh

Where a river enters the sea the pattern of wetland habitats is governed not only by river processes, channels, and sediments, but also by the gradient of salinity up the estuary and into the tidal stretch of river. In Fiordland the marshes at the heads of long fiord arms are less saline than in estuaries elsewhere. This is because the very high rainfall results in a surface layer of relatively fresh water that overlies, and does not readily mix with, the underlying seawater of the fiord.

Fig. 112 Estuarine saltmarsh where the Camelot River enters the head of Bradshaw Sound, Fiordland. The steep-sided valley was sculpted by a glacier. Since the end of the last glaciation, river alluvium has partly filled the valley floor and formed a delta at the fiord head. This photo was taken at about low tide.

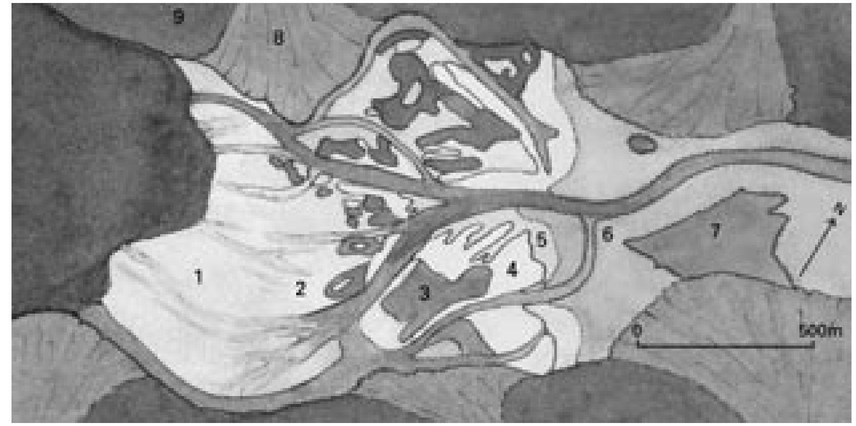

Fig. 113 Map showing pattern of habitats and vegetation types at the Camelot River mouth, Fiordland.

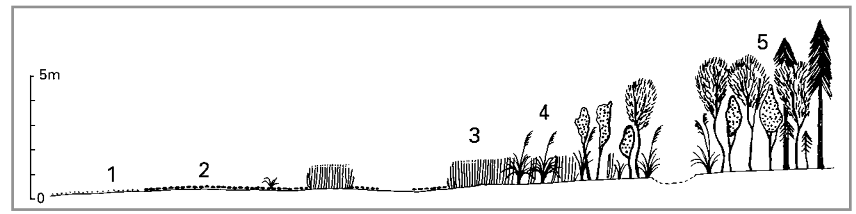

Fig. 114 Profile diagram showing habitats and vegetation types at the Camelot River mouth. The numbered features (see also Fig. 113) are:

1. Gravelly mudflats with algae in lower intertidal zone;
2. *Samolus repens* turf saltmarsh with *Poa astonii* tussocks, intertidal;
3. Oioi (*Apodasmia similis*) restiad rush saltmarsh, upper intertidal;
4. Toetoe (*Cortaderia richardii*) grass saltmarsh in uppermost intertidal zone;
5. Scrub marsh of *Carmichaelia australis*, *Coprosma propinqua*, and young kahikatea in supratidal zone, often flooded by river;
6. Forest of kahikatea, silver beech, and rimu (*Dacrydium cupressinum*) on river levees and alluvial flats;
7. Backswamp with flax - *Carex* spp. swamp;
8. Broadleaved forest (non-wetland) on steep stream fans;
9. Silver beech - kamahi (*Weinmannia racemosa*) forest (non-wetland) on very steep hillsides.

FOUR

Processes: how wetlands function

The main drivers – or environmental functions – that govern wetland diversity are hydrology, nutrient status, and substrate. Hydrology is concerned with the origin and movement of water. Nutrient status refers to soil or water fertility in the sense of how much nutrient is available for plant growth. Wetland substrates or soil materials are composed of two classes of material: organic matter derived from living organisms which may accumulate as peat; and mineral (or inorganic) matter which originates from rocks or their weathering products. The nature of wetlands is also affected by 'feedback' from ecological processes happening within them. Furthermore, most wetlands change in character over both short and long time scales.

4.1 Hydrology

Wetland types and their vegetation are determined by combinations of four main hydrological factors: water source, movement, fluctuation, and periodicity of wetness. Together these can be referred to as the water regime.

4.1.1 Water source

Water precipitates from the atmosphere mainly as rain, but also as mist, drizzle, dew, snow, and hail. Water from these sources is generally very low in nutrients, but by no means devoid of them. The least fertile classes of wetland are solely rain-fed and they occur on hill crests, flat terraces, or parts of peatland that have developed a raised dome. Water that has been in contact with rock or mineral soil picks up dissolved nutrients, as well as suspended sediments, sufficient to make a significant difference to

the general fertility of any wetlands downslope or downstream. Runoff water can enter a wetland via stream or river channels, as surface flow across adjoining land, or else as subsurface groundwater, which may move not only downslope and laterally but also upwardly, when forced up by hydrostatic pressure from a lower level. For many wetlands their moisture source (or drainage impediment) is an adjacent water body such as a lake, pond, or river.

Terms concerning water source that appear in the literature and can be useful descriptors are: ombrogenous, for an entirely rain-fed wetland; soligenous, when water supply carries inputs of dissolved nutrients from adjacent land; and topogenous, for a wetland formed behind a topographic barrier that impedes drainage, especially in situations having a relatively small catchment and therefore receiving a water supply mainly from rainfall, such as a peatland between sand dunes.

4.1.2 Water movement

Characteristics of water flow and accumulation govern oxygenation, nutrient supply, sediment delivery, and erosion patterns in wetlands. Water flow is most familiar from the visible examples of headwater seepages and streams combining to become rivers which proceed downhill through rapids, past confluences, and around meanders, until they meet the ebb and flood of their tidal reaches, the mixing zone of the estuary, and finally the sea. This well-known part of the hydrological cycle also has its hidden equivalents below the ground surface, and it is important to realise that water is forever being exchanged in both directions between the surface and underground. Different parts of wetlands have areas of active flow, of water accumulation, and even of stagnation. Rates of water movement vary greatly, as does the direction of flow. Wetlands can be discharge areas or recharge areas for groundwater and this can change over time.

Water flow features are sometimes used to distinguish three broad units of wetlands: outflow wetlands that receive only precipitation (bogs, pakihi and gumland); throughflow wetlands (fens, swamps, marshes, seepages, rivers, and most lakes); and inflow wetlands that are a sink for water accumulation (especially ephemeral wetlands in depressions).

Ward & Lambie (1999b) provide descriptors of water movement for a draft classification of riverine wetland classes. Water flow can be stable (allowing attached macrophytes and mosses to persist from year to year), variable (allowing development and scouring of macroalgae), or flashy (allowing development of little more than microalgal felts). Channel gradients can be described as steepland (high gradient, producing well-aerated broken water surfaces), midland (overall flows of moderate gradient dominated by runs / riffles, or lowland (low gradient with slow runs and pools).

The exit of water from wetlands is governed by surface outlet levels, ground permeability, evaporation from soil, water, and wetted plant surfaces, and by transpiration of water from within plants through their foliage. The term evapotranspiration is used for the combined loss of water by evaporation plus transpiration.

4.1.3 Water fluctuation

Fluctuation of level in open bodies of water is an obvious visible phenomenon. The highest level reached by water can often be inferred from the uppermost line of stranded litter, of silt deposited on plants, or erosion of soil. The amplitude of fluctuation in lakes and ponds can often be reckoned by observing how much separation there is between zones of wholly aquatic and typical terrestrial vegetation. Also very obvious is tidal fluctuation (see Figs 55 and 56), as a twice-daily event, though it must be remembered that every tide is different from the last. Spring tides have the greatest amplitude, occurring twice each month near the time of new moon and full moon, when gravitational pull of sun and moon is combined. Neap tides are those of least range in the intervening periods. Tidal amplitude in New Zealand is mainly 2–4 m, varying between different parts of the coast. Tidal fluctuation in the estuarine hydrosystem governs the distribution of subtidal, intertidal, and supratidal zones. Tidal reaches of rivers experience not only tidal fluctuation, but also the regular alternation of ebb and flood flow, both influences gradually decreasing upstream. Fluctuation in the level of flowing waters – rivers and streams – is accompanied by changes in the volume and rate of flow, and a flooding river will often greatly increase its channel width.

Much less obvious is the fluctuation of water level under the ground surface. It is measured by the position of the water table, below which the ground is saturated, and revealed by the level to which water accumulates in an excavated pit (see Figs 26 and 129). The water table is not necessarily

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level like the surface of a lake; it can vary across the land depending on land contours and permeability. Some wetlands sit upon a perched water table, one that is held up by an impermeable soil horizon such as dense silt or an iron pan that prevents drainage, even though there may be permeable materials beneath. A perched water table can also be temporary, e.g. for a period following rain or surface flooding when an upper soil horizon becomes saturated, yet not to a depth sufficient to link with a much lower saturated horizon.

The water table tends to be high and relatively constant in bogs and fens, very high (i.e. above parts of the ground surface, but also variable) in swamps, widely variable in marshes, and extremely variable in ephemeral wetlands.

Types of wetness are important in understanding wetlands. Thus, a substrate may be moist (i.e. slightly wet), saturated (with all pores fully charged with water), or submerged (flooded or ponded). The term flooding is most specifically used to describe inundation by storm runoff from adjacent land, overflow from a stream or river, or the rise in water associated with tidal inflow. The term ponding is a better descriptor for water that collects in basins or depressions.

Rainfall at any season will cause regular minor fluctuations upon any general annual pattern, but unusually heavy rains, wet seasons, or wet years can fully recharge wetlands irrespective of time of year.

4.1.4 Periodicity

The effects of fluctuation are dependent on the time factors of duration (how long), frequency (how often), and timing (Tiner 1999). The following descriptors can be applied to conditions of flooding, ponding, and saturation, and conversely to situations of being emergent, dry, or droughted: permanent (always), near-permanent (throughout the growing seasons of most years), seasonal (during one or more seasons of the year), temporary (for periods of about 2 weeks or less during the growing season), intermittent (in one or a series of wet years but not every year), episodic (rarely, say once every few years), and tidal. The term ephemeral describes situations having a pronounced alternation between prolonged periods of both wetness and dryness.