Glossary

Aquifer
Geological formations consisting of highly permeable layers of sub-surface material that transmit and provide substantial quantities of water. There are three types of aquifers and these include:

- Unconfined: An aquifer underlying the water table. The upper boundary of an unconfined aquifer is the water table
- Semi confined: Intermediate between unconfined and confined aquifers. Partly confined by layers of low permeability through which transmission of water may still occur
- Confined: An aquifer lying between two layers of impermeable material

Bypass flow
The preferential movement of water through more permeable pathways (macropores) that by pass the soil matrix.

Cation Exchange Capacity (CEC)
The cation exchange capacity (CEC) of a soil is a quantitative measure of the soils ability to hold exchangeable ions.

Contaminants
In the context of this report:

- Excess nutrients – phosphorus and nitrogen
- Sediment
- Faecal micro-organisms (microbes)

Denitrification
An anaerobic dissimilative pathway in which nitrate is used as an electron acceptor for anaerobic respiration to generate energy. It is an important process that removes nitrate from agricultural runoffs and effluent of treated waste water. It is affected by many factors such as oxygen availability, temperature, nitrate concentration, organic carbon supply and vegetation type and availability. Denitrification is strictly an anoxic process and is sensitive to oxygen levels.

Groundwater
Subsurface water occurring in the saturated zone below the water table.

Hydro(biogeo)chemistry (Hydrochemistry)
The study of these processes and how they interact may be referred to as *Hydrobiogeochemistry.* However, for simplicity we use the term hydrochemistry to refer to these broader processes. It is important that these processes are part of an integrated. Hydro(biogeo)chemistry also includes isotope hydrology and isotope biogeochemistry. More detailed constituents are listed below:

- *Inorganic constituents* comprise the majority of dissolved substances in natural waters, including all elements except those that are classified as nutrients in this report. The inorganic constituents are subdivided on the basis of typical concentration ranges in natural waters:

Major inorganic constituents are typically present in natural waters at concentrations in excess of 1 mg/L[1] and include calcium (Ca), magnesium (Mg), sodium (Na) and potassium (K), bicarbonate (HCO_3), chloride (Cl) and sulphate (SO_4). In natural waters Ca, Mg, Na and K exist predominantly as cations (positively charged ions), whereas HCO_3, Cl and SO_4 exist predominantly as anions (negatively charged ions). These four cations and three anions are collectively referred to as the *major ions*. Silica (SiO_2) is also a major dissolved constituent of most natural waters, but it is neutrally charged and therefore is excluded from the list of major ions.

Minor inorganic constituents are typically present in natural waters at concentrations between 0.001 and 1 mg/L and include carbonate (CO_3); the halide[2] anions bromide (Br), fluoride (F), iodide (I); the metals iron (Fe), manganese (Mn), cadmium (Cd) and zinc (Zn); the metalloids[3] boron (B), arsenic (As) and molybdenum (Mo); and the dissolved gases carbon dioxide (CO_2), hydrogen sulphide (H_2S); methane (CH_4) and radon (Rn). The concentrations of Fe and Mn are strongly controlled by redox potential (see Section 2.4.5) and under certain conditions may exceed 1 mg/L.

- *Nutrients* are defined in this report as nitrogen, phosphorus and organic carbon, the form and concentration of which can be strongly affected by human activities:

  The form of dissolved nitrogen in natural waters is strongly affected by oxidation-reduction potential (see Section 2.4.5), existing predominantly as either nitrate (NO_3) or ammonium (NH_4), with minor amounts of nitrite (NO_2) and/or organic nitrogen in carbon compounds (e.g. proteins) under some conditions. Total oxidised nitrogen (TON) is the sum of NO_3 and NO_2; total Kjeldahl nitrogen (TKN) is the sum of NH_4 and all forms of dissolved organic nitrogen; and total nitrogen (TN) is the sum of all dissolved and particulate forms.

  Dissolved phosphorus exists in natural waters predominantly as the phosphate anion (PO_4). This form is referred to as dissolved reactive phosphorus (DRP) because its analysis is based on its reactivity toward a particular reagent. Total dissolved phosphorus (TDP) is the sum of DRP and all dissolved organic phosphorus compounds, e.g. phosphodiesters; and total phosphorus (TP) is the sum of all dissolved and particulate forms.

  Dissolved organic carbon (DOC) is the sum of all the myriad compounds that contain carbon, excluding the inorganic forms HCO_3, CO_3 and CO_2. Total organic carbon (TOC) is the sum of all dissolved and particulate forms, excluding the inorganic forms.

- *Isotopes* are forms of an element that contain the same number of protons but a different number of neutrons in the nucleus. The ratios of the isotopes of an element in a particular compound are affected by various chemical, physical and biological processes that cause different degrees of isotopic fractionation. This study considers selected isotope ratios of hydrogen, oxygen, carbon and boron because of their relevance to the hydrologic system. The naturally occurring isotopes of the element hydrogen all have one proton but have either one,

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1 Milligrams of solute per litre of solvent (mg/L) is the most common unit of concentration used in hydrochemistry. It is equivalent to grams per cubic metre (g/m^3) and also equivalent to parts per million (ppm). Note that a capital L is used as the abbreviation for litre because a lower case l, which is also a widely accepted abbreviation, is nevertheless difficult to differentiate from the number 1 in many fonts.

2 The halide anions are the ionic form of halogen elements, i.e. the elements of Group 17 of the Periodic Table. Cl is also a halide anion but in this report it is classified as a major inorganic constituent because its concentration in natural waters is typically above 1 mg/l.

3 A metalloid is an element that has the chemical properties between those of metals and non-metals. Metalloids typically exist in natural waters in the form of oxyanions, e.g. BO_3^{3-}. Si is also a metalloid but in this report it is classified as a major inorganic constituent because its concentration in natural waters is typically above 1 mg/l.

two or three neutrons in the nucleus, and are called protium (^{1}H), deuterium (^{2}H) and tritium (^{3}H), respectively. The ratios of ^{2}H and ^{3}H to ^{1}H in the water molecule are used in this study to infer water source and age. The ratios of the oxygen isotopes ^{18}O to ^{16}O in the water molecule and inorganic carbon are also used to provide information about water source and age. The ratio of ^{11}B to ^{10}B is used to infer the sources of boron and nitrogen, respectively. Water samples have also been analysed for the ratios of ^{15}N to ^{14}N and ^{18}O to ^{16}O in NO_3, but these results are reported elsewhere (Baisden *et al*., in prep.).

- *Microbiological parameters* quantify the concentration of various bacterial species. All natural waters contain a variety of indigenous bacteria, but most water quality monitoring programmes specifically aim to quantify the concentration of non-indigenous bacteria that indicate contamination by human or animal waste. The total coliform (TC) concentration enumerates 16 different bacterial species that are found in soil, vegetation, animal wastes and human sewage. The faecal coliform (FC) concentration enumerates the subset of six bacterial species that are found in human and animal waste. *Escherichia coli* (E. coli) and Enterococci (Entero) are two specific species that indicate faecal contamination by warm-blooded animals.
- *Other* hydrochemical parameters are also routinely monitored to provide insight into the chemistry of a natural waters, including: water temperature (Temp); electrical conductivity (EC) and/or the concentration of suspended solids (SS), which indicate the total concentration of dissolved or suspended substances in the water sample; pH, a measure of acidity; dissolved oxygen concentration (DO) and oxidation-reduction potential (ORP), which indicate the water's redox status (see definition in Section 2.4.5); and clarity and turbidity, measures of the total concentration of suspended solids (e.g. minerals and/or organic materials).

Ion Exchange
Most soils carry a net negative charge which is neutralised by positively charged cations which are attached to, or accumulate at, the surface of soil particles. Such cations are not retained indefinitely by soil materials but remain in equilibrium with cations in soil waters with which they can exchange (a process termed *ion exchange*).

Macropores
Fractures in the soil that are created by earthworms and cracking of the soil due to wetting and drying. These allow rapid transport of water, solutes and colloids. Water flows freely through macropores

Recharge
Replenishment of saturated zones by percolation of precipitation and surface water or through lateral movement of ground water from adjacent aquifers.

Redox
An oxidation-reduction (termed *redox*) reaction is a type of chemical reaction that involves a transfer of electrons between two chemical species. In natural waters and soils, redox reactions are largely driven (catalysed) by bacteria, which gain energy by facilitating the transfer of electrons from organic matter to an electron acceptor. This process results in the breakdown of organic matter into its constituent elements (carbon, oxygen, nitrogen, phosphorus and some minor trace elements), the consumption of the electron acceptor, and a net energy release for the micro-organism.

In the natural environment, the redox state of soil and groundwater reflects the chemical characteristics of the soil and aquifer substrates through which the water has passed since recharge. The redox status of a soil can be characterised in term of its drainage characteristics (represented by gleying) and organic carbon content (Killick *et al.*, 2014).

Residence Time
The average length of time that water will remain in a reservoir

Soil
Earth material comprising of organic matter, water, gases, decomposed rocks and unconsolidated sediments formed as a result of the interaction of parent material, climate, fauna and flora over a period of time.

Soil matrix
The solid component of the soil. Consists of particles that vary in chemical and mineralogical composition as well as in size, shape and orientation. Also contains organic material.

Soil Water
The total amount of water in the vadose zone (unsaturated zone).

Surface Water
Bodies of water above the surface of the earth, e.g. lakes, streams, ponds, wetlands

Physiographic Unit
A geographically defined territory with specific litho-geomorphic features, relief and land cover patterns

WAL2020
Environment Southland's Water and Land 2020 & Beyond project, which includes a range of measures aimed at halting the decline of Southland's water quality by promoting best practice land management and developing a water and land plan that updates existing policies and rules

Water Quality
The condition of water relative to ecological or human requirements.

Water quality in an individual waterbody reflects the cumulative influence of a range of factors including land use, topography, hydrology, geology and hydrochemistry in the contributing recharge area, as well as the physical and biological characteristics of the waterbody itself.

Weathering
Chemical weathering is a process whereby interaction between acidic soil waters and rock and soil minerals consumes carbonic acid and releases ions bound in the mineral structure into solution. Chemical weathering both directly and indirectly influences water quality due to the dissolution of rock minerals as well as the formation of clay minerals which influences the hydraulic characteristics of rock and soil materials.

Hydromorphic approach

An approach that uses substance migration, accumulation, transformation, soil evolution and pedogenetic processes to understand characteristics of the environment such as hydrochemistry and water quality.