8.6 Catchment permeability

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Preamble: To be useful, the "catchment permeability" attribute needs to be defined in relation to what stress is being managed and what outcome or objective will be impacted. The following examples illustrate the current issue for three different contaminant stressors:

- Heavy metals concentration is linked to (among other things) the level of imperviousness in urban catchments, but less so in rural catchments [1-4].
- Diffuse nitrogen pollution is linked to (among other things) the interaction of land use with surface water/groundwater interaction and pathways, the presence/absence of an aquifer, aquifer movement and characterisation and/or presence of a denitrification zone in the aquifer [5-9].
- Sediment source and transport is linked to (among other things) the soil-type, land cover characteristic, position in the catchment and rainfall intensity [10-12].

The lack of a more precise definition translates to different measurements or estimations of catchment permeability ranging from GIS analysis (e.g., level of imperviousness in relation of discharge of metal contaminants to waterways [1]) to inverse hydrological and transport modelling (e.g., estimation of contaminant residence time within groundwater system or watershed soil hydraulic conductivity [7]).

In the absence of a formal definition the author considers catchment permeability to be "how quickly or readily water percolates through the soil profile/subsurface environment".

State of knowledge of the "Catchment permeability" attribute: Poor / inconclusive – based on a suggestion or speculation; no or limited evidence

The status of knowledge answer is associated with the multiple definitions attached to the attributes in regards of the multiple stressors that we aim to manage for.

<u>Part A—Attribute and method</u>

A1. How does the attribute relate to ecological integrity or human health?

Depending on the contaminant or hydrological stressor considered, there is a body of evidence that catchment permeability is associated with ecological integrity and human health. For example, the level of imperviousness in urban catchments is often linked to trace metal concentrations in urban streams and their impacts on ecological integrity [3].

A2. What is the evidence of impact on (a) ecological integrity or (b) human health? What is the spatial extent and magnitude of degradation?

Previous studies have identified "catchment permeability" as one of the delivering pathways of impact of land management activities on receiving water bodies [2,5,7]. As such, catchment permeability is an indicator of various aspects of water delivery to receiving environments. High permeability is the inverse of high impervious (paved) surface, the latter of which can increase the "flashiness" of water delivery to receiving environments and transport urban contaminants (metals, hydrocarbons, etc) that are mobilised in runoff from paved surfaces into waterways. Increased permeability is anticipated to reduce surface runoff and allow water to percolate below-ground and to be subsequently transported by subsurface flows to receiving waters.

A clear and concise interpretation of this attribute is likely to be important if it is to be used as a metric of stressors and ecology integrity. Moreover, the coarser the spatial resolution under consideration, the more complex the conceptualisation of the catchment permeability attribute is likely to become.

A3. What has been the pace and trajectory of change in this attribute, and what do we expect in the future 10 - 30 years under the status quo? Are impacts reversible or irreversible (within a generation)?

Catchment permeability is likely to have decreased over time with increased urbanisation and associated creation of impervious surfaces (e.g., roads, paving, buildings). This trend is expected to continue under the status quo. Use of mitigation systems can help to slow or reverse that trajectory. For example, mitigation systems can be put in place to collect impervious area runoff and to control metal concentrations in stormwater (e.g., https://niwa.co.nz/freshwater/stormwater-management/characterising-stormwater-quality). However, the development of mitigation systems such as porous pavement and porous road asphalt to reduce flood risk are also likely to impact pathways of delivery of contaminants to waterways [13]. For example, water and contaminants will percolate into soil and groundwater and be transported to receiving waters via subsurface flow pathways (i.e., interflow, groundwater) instead of via surface runoff. Some contaminants might be better removed from water if they are transported by these flow pathways (e.g., nitrate removed by denitrification or vegetation uptake).

A4-(i) What monitoring is currently done and how is it reported? (e.g., is there a standard, and how consistently is it used, who is monitoring for what purpose)? Is there a consensus on the most appropriate measurement method?

A catchment permeability attribute is not currently monitored or reported nationally or internationally. However, councils or other organisations may hold information on impervious surface layers in GIS databases. There has been research attempting to link aspects of catchment permeability to receiving water contamination by specific stressors (e.g., impervious surface area to trace metals [2-4]). Attempts have been made through numerical modelling to estimate catchment permeability [7, 9], but results generally depend on the numerical model used. Most of the models are also small scale. It is likely that a national model would need to be developed to understand changes in catchment permeability, with significant initial work required to understand how different land uses and land management impact upon catchment permeability.

A4-(ii) Are there any implementation issues such as accessing privately owned land to collect repeat samples for regulatory informing purposes?

Impervious surface area as an aspect of catchment permeability is likely to be best monitored by identifying paved areas using aerial imagery (at the scales of cities, catchments, or regions). However, catchment permeability (the named attribute, which is more than impervious surface area) is likely to be more difficult and nuanced to measure. Access to private land may be required to measure catchment permeability.

A4-(iii) What are the costs associated with monitoring the attribute? This includes up-front costs to set up for monitoring (e.g., purchase of equipment) and on-going operational costs (e.g., analysis of samples).

The answer to this question depends on the definition of "catchment permeability". As an aspect of catchment permeability, some impervious surface area data may already be held in GIS databases by councils and other organisations.

Measuring or monitoring a more nuanced attribute of catchment permeability could be significantly more difficult, especially if an assemble of stressors associated with this attribute need to be characterised.

A5. Are there examples of this being monitored by Iwi/Māori? If so, by who and how?

The author is not aware of any catchment permeability monitoring being undertaken by iwi/hapū/rūnanga. However, we are aware of the Urban CHI which could potentially be adapted to include imperviousness as an attribute (Gail Tipa, pers. comm, 20 June 2024).

A6. Are there known correlations or relationships between this attribute and other attribute(s), and what are the nature of these relationships?

A correlation or relationship is likely to exist between the catchment permeability attribute and other freshwater attributes when looking at specific stressors, as catchment permeability (which includes impervious surface area) is expected to affect the delivery pathway of other attributes to receiving water bodies (e.g., trace metals, nitrate) and the quantity of water in surface waterbodies (surface water flow alteration) and subsurface aquifers (groundwater depletion). However, few studies have characterised integral/holistic relationships between catchment permeability and other attributes.

Part B—Current state and allocation options

B1. What is the current state of the attribute?

Compared to many other countries worldwide, New Zealand, overall, has a low percentage of paved/impervious land area. Although land cover has been substantially modified since pre-human times, the human population density and amount of paved area in New Zealand is very low relative to other countries. High catchment permeability (which includes low paved/impervious surface) is generally considered to be associated with a healthy environmental state.

Our current knowledge of the attribute state in New Zealand is generally poor at regional and catchment scales. It is possible to quantify the attribute accurately at point scale, but upscaling that degree of accuracy from point scale to catchment scale is difficult. It is possible to quantify and monitor the level of imperviousness in a watershed-based on the presence of road network but the level of watershed surface imperviousness will also depend on factors including the type of road and buildings, the state of the vegetation (e.g., flushed, dry, or burned) especially in rural areas, the time of the year (summer/winter), soil compaction, and local scale topography.

B2. Are there known natural reference states described for New Zealand that could inform management or allocation options?

The natural reference state of catchment permeability is expected to be higher than present given the existence of our current road networks and urban areas which affect imperviousness. However, the natural states of other factors that affect catchment permeability (as listed in B1) are not well known.

B3. Are there any existing numeric or narrative bands described for this attribute? Are there any levels used in other jurisdictions that could inform bands? (e.g., US EPA, Biodiversity Convention, ANZECC, Regional Council set limit)

The author is not aware of any proposed bands or guidelines for a catchment permeability or impervious surface area attribute in use in New Zealand. However, there may be some guidelines for impervious surface area in relation to stormwater contaminants in the overseas literature.

B4. Are there any known thresholds or tipping points that relate to specific effects on ecological integrity or human health?

The author is not aware of any specific thresholds relating catchment permeability to ecological integrity. The author considers that specific thresholds may depend on the individual contaminant or hydrological stressors that are affected by catchment permeability (e.g., nitrate, trace metals, surface water flow alteration, groundwater depletion) being considered. These stressors, in turn, affect ecological integrity in ground and surface waters.

B5. Are there lag times and legacy effects? What are the nature of these and how do they impact state and trend assessment? Furthermore, are there any naturally occurring processes, including long-term cycles, that may influence the state and trend assessments?

Depending on the stressor considered, lag times and legacy effects may be important. Subsurface and groundwater pathways associated with nutrient management will be affected by catchment permeability. Currently hydrological/water quality modelling is used in association with isotope hydrology to assess lag times in the delivery of nitrogen (usually as nitrate) to rivers. However, this may be a stressor specific response, and a holistic approach considering multiple stressors and using consistent approaches to determine lag time for multiple stressors (e.g., nitrate, trace metals, surface water flow alteration, groundwater depletion) is likely to be required.

In general, the amount of impervious surface area in New Zealand is expected to continue to rise as it is highly unlikely for road networks or urban areas to ever be retired once they are constructed. However, use of water sensitive design elements in urban areas (e.g., porous pavements, raingardens, stockholm tree pits, wetlands) and in rural areas (e.g., wetlands, riparian buffers) may help to improve the permeability of modified land surfaces.

B6. What tikanga Māori and mātauranga Māori could inform bands or allocation options? How? For example, by contributing to defining minimally disturbed conditions, or unacceptable degradation.

In addition to discussing this attribute directly with iwi/hapū/rūnanga, in regards to catchment permeability, there may be tikanga and mātauranga Māori relevant to informing bands, allocation options, minimally disturbed conditions and/or unacceptable degradation in documents like iwi environmental management and/or climate change plans etc. For example, the Iwi Management Plan for Ngāti Whātua Ōrākei outlines tikanga (engagement protocols) and their priorities on any matters which effect the lands, air and water within the rohe which includes “any proposal which creates an impervious area greater than 5000 m^2” [14]. The Ngāti Whātua Ōrākei Kaitiakitanga Framework also specifically references objectives for water sensitive urban design [15].

Many iwi economic entities themselves have substantial urban property portfolios that include commercial and residential investments [e.g. 16], where three iwi, Ngāi Tahu, Ngāti Whātua o Ōrākei, and Waikato-Tainui, currently own the greatest share [17]. Iwi urban property investment is predicted to increase as more groups settle their claims [18, 19].

Part C—Management levers and context

C1. What is the relationship between the state of the environment and stresses on that state? Can this relationship be quantified?

Catchment permeability, or the ease at which water can percolate through the soil profile or subsurface environment, is expected to decrease in response to an increase in urban and rural development activities including construction of roading, paved surfaces, buildings, soil surface sealing and compaction.

C2. Are there interventions/mechanisms being used to affect this attribute? What evidence is there to show that they are/are not being implemented and being effective?

C2-(i). Local government driven

In urban areas, porous pavements, stockholm tree pits, raingardens and wetlands are being used by some councils to retain water and lessen the downstream impact of stormwater flows and to reduce contaminant loads to receiving waters. In rural areas, many councils support the establishment of riparian buffers and the protection and/or creation of wetlands. Establishment of these urban and rural interventions are expected to increase catchment permeability.

C2-(ii). Central government driven

Central government requires the protection of natural wetlands >500 m^2 in size which is expected to enhance catchment permeability.

C2-(iii). Iwi/hapū driven

As mentioned in B6, iwi/hapū planning documents such as Environmental Management Plans and Climate Change Strategies/Plans may contain policies/objectives/methods seeking to influence catchment permeability outcomes for the benefit of current and future generations. The author is unaware of any other iwi/hapū driven interventions/mechanisms being used to affect this attribute except for projects that create riparian buffers, protect and create wetlands (e.g., funded by the Waikato River Authority) and encourage water sensitive urban design (including by iwi entities themselves)

C2-(iv). NGO, community driven

The establishment of riparian buffers and protection and creation of wetlands by NGO's (e.g., New Zealand Landcare Trust) and catchment groups is expected to increase catchment permeability.

C2-(v). Internationally driven

We are unaware of internationally driven interventions/mechanisms being used to affect this attribute. However, there is the IPBES and the Nature Futures Framework which may have parts that are relevant.

Part D—Impact analysis

D1. What would be the environmental/human health impacts of not managing this attribute

Without any checks or controls, urban expansion and uncontrolled growth will result in the widespread paving of our natural areas, which would have negative impacts on numerous aspects of terrestrial, freshwater, and coastal marine ecosystems. In the rural sector, high intensity farming with livestock can lead to soil compaction decreasing catchment permeability. The negative consequences of decreased catchment permeability include: increase in surface runoff leading to increased erosion and risk of downstream flooding, decrease in recharge of groundwater and river baseflows and decrease in removal of contaminants from water associated with biological assimilation and transformation processes.

In turn, the consequences of decreased catchment permeability can have detrimental effects on ecology integrity and human health including i) insufficient river flows to support aquatic life, ii) contaminant levels in groundwater and surface water that are harmful to aquatic life and iii) depletion of groundwater and surface that can concentrate contaminants that are pose human health risks (e.g., nitrate, trace metals).

D2. Where and on who would the economic impacts likely be felt? (e.g., Horticulture in Hawke's Bay, Electricity generation, Housing availability and supply in Auckland)

The economic impacts of decreased catchment permeability are likely to be felt by those communities that are affected by increased erosion and heightened risk of downstream flooding that threatens homes, livelihoods (e.g., agricultural enterprises) and infrastructure, by decreased groundwater and surface water supplies for drinking water and irrigation, and costs associated with the treatment of contaminated ground and surface waters for drinking water, irrigation and other purposes. Both urban and rural communities throughout New Zealand are expected to be economically impacted by the effects of reduced catchment permeability, but the impacts are likely to be most strongly felt in lowland areas of large catchments, with a high degree of urbanisation and/or intensive agriculture.

D3. How will this attribute be affected by climate change? What will that require in terms of management response to mitigate this?

Rainfall and storm frequency/intensity is expected to increase with climate change. This could interact with catchment permeability to affect runoff volumes and water quality. Fire and drought frequency could also increase which could lead to an increase in the sealing of soil surfaces. Climate change could affect catchment permeability in a number of ways, but we do not currently have the tools to make confident predictions about the significance or direction of the changes.

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