Assessing water footprint and associated water scarcity indicators at different spatial scales: A case study of concrete manufacture in New Zealand

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Amber Evelyn Mellor

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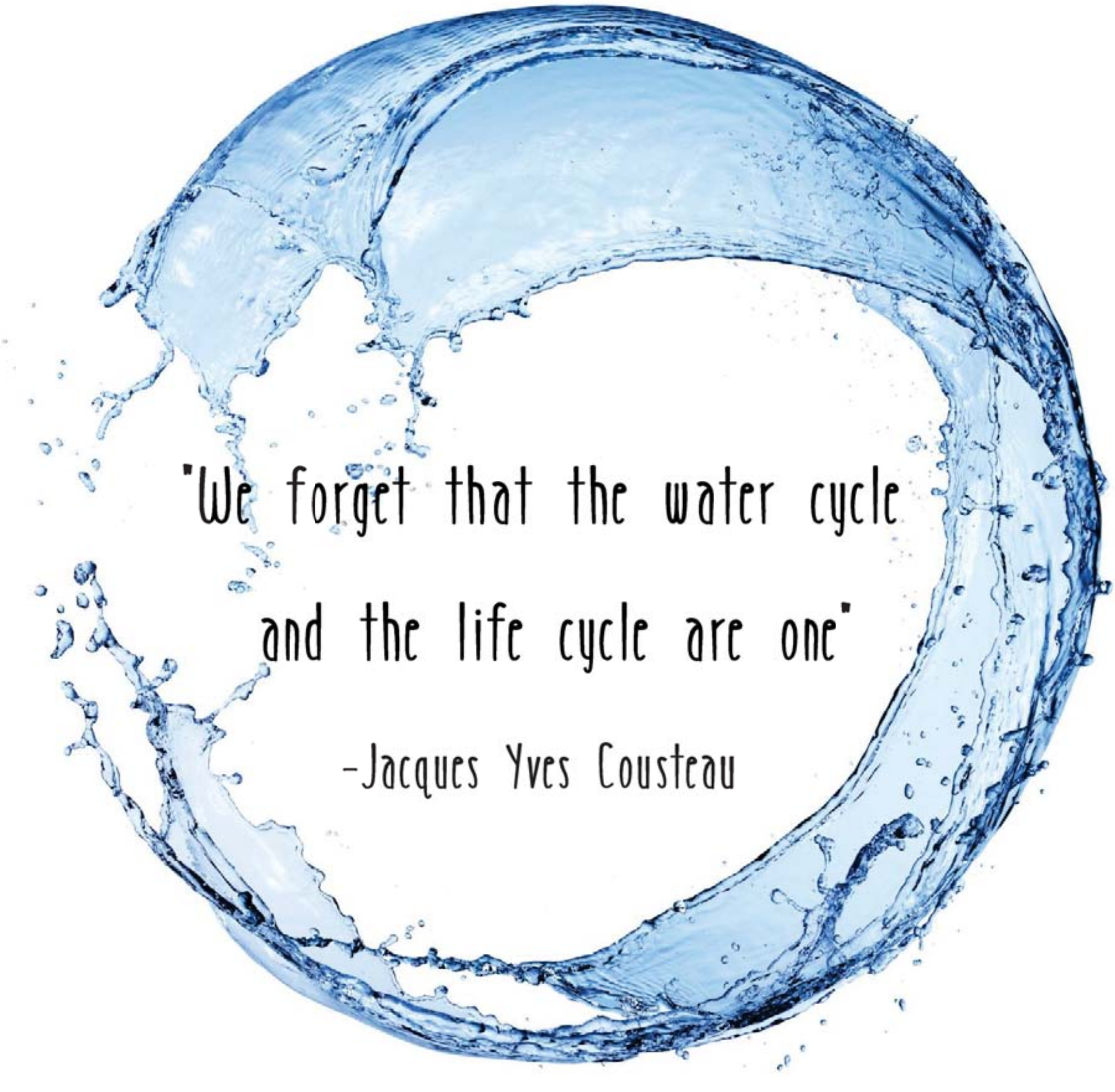

"We forget that the water cycle
and the life cycle are one"

-Jacques Yves Cousteau

Abstract

Water scarcity is a growing issue of concern across the globe. In recent times a complex suite of water footprint impact assessment tools and concepts have supplemented traditional management approaches. There are several methods proposed in the literature to both quantify water use and assess its environmental impacts at defined spatial scales. In New Zealand, case studies in the water footprinting space are sparse, and are for the majority focused on the agricultural industry.

This thesis focused on evaluation of different water footprint methods and their associated water scarcity indicators to assess water use impacts for the building and construction sector of New Zealand. The water footprints of 1 m^3 ready mix concrete manufactured at 27 concrete batching plants throughout New Zealand were calculated at three distinct spatial scales: the freshwater management zone scale, catchment scale, and regional scale. Four water footprint characterisation factors (blue water scarcity (WS_{blue}) (Hoekstra et al., 2011), water stress index (WSI) (Pfister et al., 2009), water depletion index (WDI) (Berger et al., 2014), and available water minus demand (AMD) (Boulay et al., 2016)) were used to assess the environmental impact of water use for 1 m^3 ready mix concrete at the three spatial scales.

The average volumetric blue water footprint of the 27 ready mix batching plants was quantified at 0.18 m^3 (180 litres) of water per m^3 of concrete, and ranged from 0.15 (150 litres) to 0.29 m^3 (290 litres) of freshwater per m^3 of concrete. For three of the four water footprint methods used (WDI, WSI and WS_{blue}), and across the three spatial, the Ashburton boundary ranked highest in terms of the environmental impacts of a specified quantity of water use. In contrast, the AMD method ranked the Palmerston North boundary highest across the three spatial scales. At the freshwater management zone and catchment scales, the WDI, WSI and WS_{blue} methods ranked the Wanganui area lowest, and the AMD method ranked the Greymouth area lowest. At the regional scale, all the four water footprint methods ranked the West Coast region lowest in terms of the environmental impact of water use, due mainly to the fact that the West

Coast has more available water and a lower allocation demand than other regions studied. The analysis indicated that volumetric water use varied by a factor of two across the different plants (per m^3 concrete). For three of the four WF methods (WDI, WSI and WS_{blue}), the WF results were similar in their rankings of the different plants at all the geographical scales; however, the AMD method resulted in different rankings at all the geographical scales. Overall, the WDI and WSI water scarcity indices calculated by Berger et al. (2014) and Pfister et al. (2009) were less readily adaptable to the finer resolution in New Zealand. The WS_{blue} and AMD calculated by Hoekstra et al. (2011) and Boulay et al. (2016) however, were found to be more readily adaptable. It is recommended that these methods be explored further with respect to their potential use at the finer resolution in New Zealand.

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List of Abbreviations

Acronym	**Definition**
EFR	Environmental Water Requirement
LCA	Life Cycle Assessment
WFN	Water Footprint Network
ISO	International Standardisation Organisation
GIS	Geographic Information System
WSI	Water Stress Index
LCIA	Life Cycle Impact Assessment
WAVE	Water Accounting and Vulnerability Evaluation
WTA	Withdrawal-to-Availability Ratio
LCI	Life Cycle Inventory
BIER	Basin Internal Evaporation Recycling Ratio
WDI	Water Depletion Index
CTA	Consumption-to-Availability Ratio
SWS	Surface Water Stocks
WULCA	Water Use Life Cycle Assessment
AWaRe	Available Water Remaining
FMZ	Freshwater Management Unit
SI	Supplementary Information

Glossary of Terms

Water Stress The ability, or lack thereof, of water to meet human *and* ecological demands

Water Scarcity The lack of available freshwater required to meet water usage demands for a particular region

Surface Water Water that is on the Earth's surface, such as in a stream, river, lake, or reservoir.

Groundwater Groundwater is the water stored beneath Earth's surface in aquifers (layers of water-bearing rock or sand). Groundwater exists in the zone of saturation, and may be fresh or saline

Blue Water Refers to the consumption of surface and groundwater resources

Green Water Refers to the consumption of precipitation on land- insofar as it does not become runoff

Grey Water[1] Refers to pollution, and can be described as the volume of freshwater required to assimilate a pollutant load given natural background conditions and existing ambient water quality standards

[1] Defined according to water footprint terminology