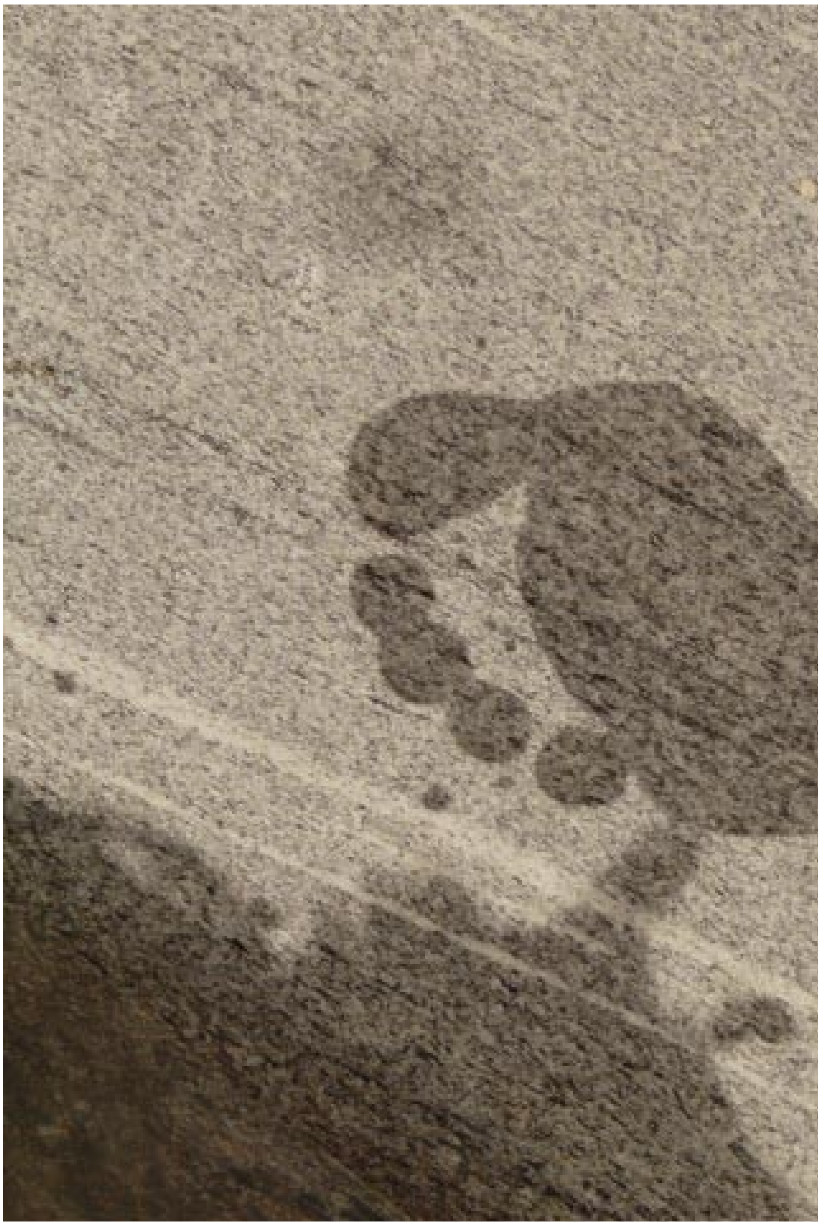
The water footprint of buildings and why it doesn't matter

In these days of endless metrics of building performance, Dr Judith Thornton discusses why the water footprint of your building is one thing you probably don't need to concern yourself with, at least for now.

First it was ecological footprints, then carbon footprints, and then more recently the world has apparently woken up to water footprints. The phrase 'virtual water' was coined by Tony Allan in 1994 when he sought to explain the relative lack of inter-state conflict in the Middle East.[1] He hypothesised that countries were importing virtual water in the form of grain products, thereby freeing up their local water resources for municipal uses and potentially avoiding conflicts between countries trying to secure water resources.[2]

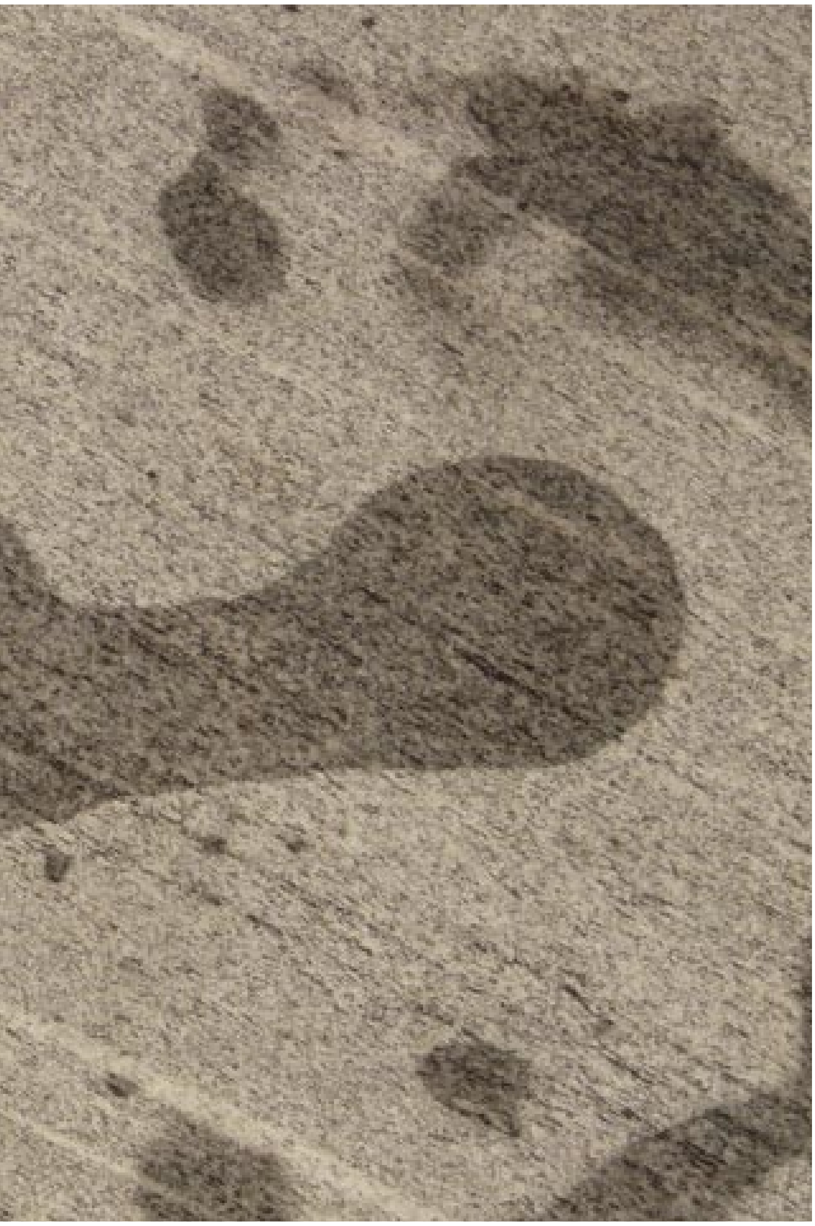
Given the popularity of the carbon footprint at the time, it wasn't long before a group of academics at the University of Twente in the Netherlands merged the two concepts into the water footprint, and later formed the water footprint network (WFN). As defined by the WFN, the water footprint is the volume of water consumed over the lifecycle of a product and is made up of green, blue and grey components. Green water is the amount of precipitation that is used directly (i.e. that does not become ground or surface water). Blue water is the volume of surface and ground water sources consumed. The grey water footprint is the volume of freshwater that is required to assimilate a pollutant load.[3]

We can calculate the green, blue and grey water footprints of components and the processes that go into making them, add them together and then potentially come up with the water footprint. For example, the blue water footprint of a square metre of double glazing unit might be 400 litres, and the water footprint of constructing a building might be $3m^3/m^2$ floor area. Most of the commonly quoted water footprint figures are for food. The UK consumer is said to have a water footprint of 4600 litres per day, 3400 litres of which is attributable to agricultural products.[4] So far, so environmentally evil - we have a large footprint, we should try and reduce it. Or should we? There are four main reasons why a water footprint is inherently more complex than a carbon footprint.



Size isn't everything

The first, and most obvious reason that a volumetric water footprint is not necessarily a useful metric is that the use of one litre of water differs enormously in environmental impact depending on where and when it is used. Whilst a tonne of CO_2 released into the atmosphere has the same impact on climate regardless of where it is produced, using 1000 litres of water to produce a building material in Wales is entirely different to using that same volume of water in Australia, for example. The seasonal aspect is also important. In the UK, we have a summer water deficit which we need to meet from winter rainfall, and we do this via storage systems, both natural (groundwater aquifers) and artificial reservoirs, and so using water in the winter might be less problematic than using it in the summer, and it can also vary enormously from year to year. So without taking into account the temporal and spatial context, the 400 litres of water it took to make our double glazing unit becomes rather difficult to interpret. An entire discipline is therefore devoted to calculating weighting factors (along



with the inevitable disagreements and complexities that result.[5]

At the very least, the lack of direct relationship between the water footprint of production and its environmental impact is problematic - we cannot simply assume that small water footprints are a good thing. In terms of products and resources relevant to construction, the notion of a water footprint of timber is particularly difficult to interpret. Forests have very high transpiration rates, and therefore timber generally has a high water footprint, in the region of 1000 litres/kg dry timber, but it would clearly be ridiculous to argue that forests should be replaced by other crops on this basis or we should specify building materials other than timber because of its high water footprint.

Renewable resources, stocks and flows

The second issue that makes water footprints difficult to interpret is that water is renewable over relevant timescales; it moves through the hydrological cycle over the course of days/weeks/years, so when we say that water has been 'consumed', all we actually mean is that at that moment in time it is not liquid freshwater. It may have evaporated (e.g. in a cooling tower when producing electricity), or transpired through the leaves of vegetation. A small amount (and it always is a very small component of the water footprint) may have been incorporated into the product. Water we have 'consumed' therefore remains in the hydrological cycle and becomes available again over relatively short timescales. So thinking about 'embodied water' in the same way that we do about embodied energy or carbon is not helpful. Water that we consume in the present can also be used in the future, and it isn't going to run out in any permanent sense. Similarly, the water involved in the end-of-life fate of a building is also problematic - we cannot simply add any water used during recycling or waste management to the water used during other phases of the building life cycle and expect to have a useful number. Thinking about water in terms of stock and flow methodology and an integrated water balance is generally more helpful than the notion of a water footprint; i.e. by drawing a flow diagram of all the stocks and flows, measuring/calculating the magnitude of each stock and flow, and using these relationships to ascertain what the consequences might be of changing flow rates into/out of stocks, or diverting flows in some way, with reference to a defined time period.

The volume of interest - withdrawal or consumption?

The next thing to be wary of when looking at water footprints is that when we talk about water 'use' we are often rather vague about what we mean. When we say we have used 100 litres of water, are we referring to the volume of water withdrawn (the usual meaning in the UK) or the volume of water that has been consumed (the volume withdrawn minus the amount that is discharged back to the local environment and is therefore immediately available again for other users)? This is an important distinction, because the usefulness of withdrawal or consumption as a metric is markedly different between sectors[6]. For a hydrologist considering a watershed in which water withdrawals occur for the purposes of irrigated agriculture, the consumed volume is vitally important. This is water intrinsically linked to crop growth via transpiration, plus that evaporated from bare ground, and this water is then not available to recharge groundwater aquifers or to become surface water that might then be available for municipal or industry use. In contrast, if an identical volume of water is withdrawn for municipal water use, virtually the entire volume will be discharged again into the same watershed having undergone sewage treatment. In other words, according to the most widely used definition of water footprints (that promoted by the WFN), our domestic water footprint is almost zero, which means that in the context of the built environment, the water footprint is not a particularly useful concept - it reflects neither the importance of the water to the individual, or the impact of our use of it to the environment, and the more commonly used metric of water withdrawal is much more helpful. Both withdrawal and consumption are useful metrics in some sectors, notably electricity generation. Broadly speaking there are two main water-based cooling techniques for thermo-electric power generation (coal, gas, oil, nuclear). 'Once through' cooling withdraws very large volumes of water, but the vast majority of this is then released back into the watercourse (high withdrawal, low consumption). In contrast, indirect cooling systems operate via evaporative cooling towers; the water withdrawal volume is relatively low, but the consumed volume is much higher than for ones through cooling.[7]

Water pollution and the grey water footprint

The final, and perhaps most unhelpful part of the water footprint concept, is the idea of the 'grey' water footprint of a product or service.[8] This relates to the pollution of water caused by production and is calculated as the volume of water required to 'assimilate' the waste products arising. We might calculate that our double glazed unit had a grey water footprint of 1000 litres, because this amount of water would dilute the pollutants released to an acceptable background concentration. However, expressing a quality parameter as a volumetric quantity is a theoretical exercise (and the grey water footprint can therefore exceed the total water available in a river basin). The calculations require numerous problematic assumptions (e.g. when there is no safe environmental level of a pollutant and the assimilation volume is therefore infinite). It also pre-supposes that water pollution is a necessary consequence of production. To date the grey water footprint has found few backers, with most companies regarding standard life cycle assessment (LCA) approaches as more useful, because they consider several categories of aquatic pollution (e.g. eutrophication and ecotoxicity) and the contribution of a range of pollutants to impacts in those categories. Whilst of little use in Western Europe, the grey water footprint concept may have some value in countries with weak environmental governance regimes, where pollution in watercourses renders it completely unsuitable for abstraction by downstream users, and these users are effectively exposed to water scarcity because of a lack of treatment. A measure of the volume of water that would be required from another source (e.g. for municipal supply) as a consequence of an identifiable pollution source could therefore be a useful way of highlighting the implications of industrial pollution on other stakeholders.

Where next for water footprints?

So why is it then, when the scientific underpinning of the water footprint concept is so shaky, that it has become such a popular metric? There are two basic reasons. Firstly, the familiarity with the idea of a carbon footprint and a widespread unease about water scarcity in the face of climate change means that professionals are looking for ways to think about water. The second reason for the metric's popularity is just as simple. The results of most water footprint studies to date have produced attention-grabbingly large numbers. This is because they have been focussed on food production. Plants transpire a lot of water during growth and so have high consumptive water footprints. Water footprints are controversial in academic circles; many of the prestigious water journals do not publish water footprint studies, criticising them for their 'lack of hydrological rigour'. A specific sub-discipline within water economics has emerged, with a very different approach to calculation, and a different set of advantages and disadvantages.[9] A forthcoming EN ISO standard on water footprints will provide useful clarity (it is strongly grounded in LCA methodology, and will consequently be more rigorous on definitions, system boundaries and reporting conventions than much of the water footprint literature has been to date).[10] However, in a more general sense, the academic community has so far failed to articulate when and where these studies are useful and, perhaps more importantly, what better metrics are available for considering societal impacts on the water environment.

Given the limitations described, how much of the water footprint literature provides useful additions to knowledge? It is undoubtedly true that the concept of green water has provided useful emphasis on the importance of rain-fed agriculture. It has been estimated that a total of 7100km^3 of water are consumed annually by agriculture, of which 5500km^3 is rainfall as opposed to irrigation water. Until the phrase 'green water' was coined by the seminal work of Falkenmark & Rockstrom,[11] this aspect of the hydrological cycle which is so critical to food production, was rarely discussed by policy makers, agronomists and farmers. Understanding and quantifying this water, and considering how we can best optimise the use of rainfall by crops is clearly a serious concern, particularly given the context of rising global populations and climate change induced variability in future rainfall patterns. However, hydrologists would rightly ague that we cannot consider one part of the hydrological cycle in isolation, that the WFN notion of water consumption is flawed and that a more complete water balance is preferable to a water footprint calculation.

Whilst the WFN approach is easy to criticise, the fact that it has drawn attention to the difference between water withdrawal and water consumption is also useful. There are certainly situations in which the idea of consumption (as opposed to withdrawal) is important. The electricity generation sector has already been discussed, but withdrawal and consumption are most important at watershed scale. Multiple stakeholders (agriculture, municipal, industrial) will all have water needs, and an environmental regulator needs a means of allocating water to the various users. This requires consideration of the water quality and quantity of discharges from each sector and the extent to which these influence downstream users.[12] It might be that agricultural users should be incentivised to make better use of rainfall, and not be allowed ground or surface water withdrawals, but the consequence of 'efficient' use of rainfall in reducing surface water runoff generation and groundwater recharge must also be considered.

It is also the case that the idea of a water footprint has been useful as a marketing hook for engagement with business stakeholders. However, the fact that the water footprint calculations themselves are rarely, if ever accompanied by statements about their applicability or any kind of error margin carries with it a very real risk of subsequent confusion, misplaced objectives, disengagement and cynicism. Much as with LCA and embodied energy, the idea of producing a database of water footprints of common materials and activities also arises. However, as should be clear from the above, the lack of clarity, rigour and applicability of the water footprint concept means that it is debatable whether a database of water footprints (perhaps equivalent to the ICE carbon footprint database) will be an appropriate aim in the near future (indeed, several groups have started to construct water footprint databases only to be thwarted by data quality issues).

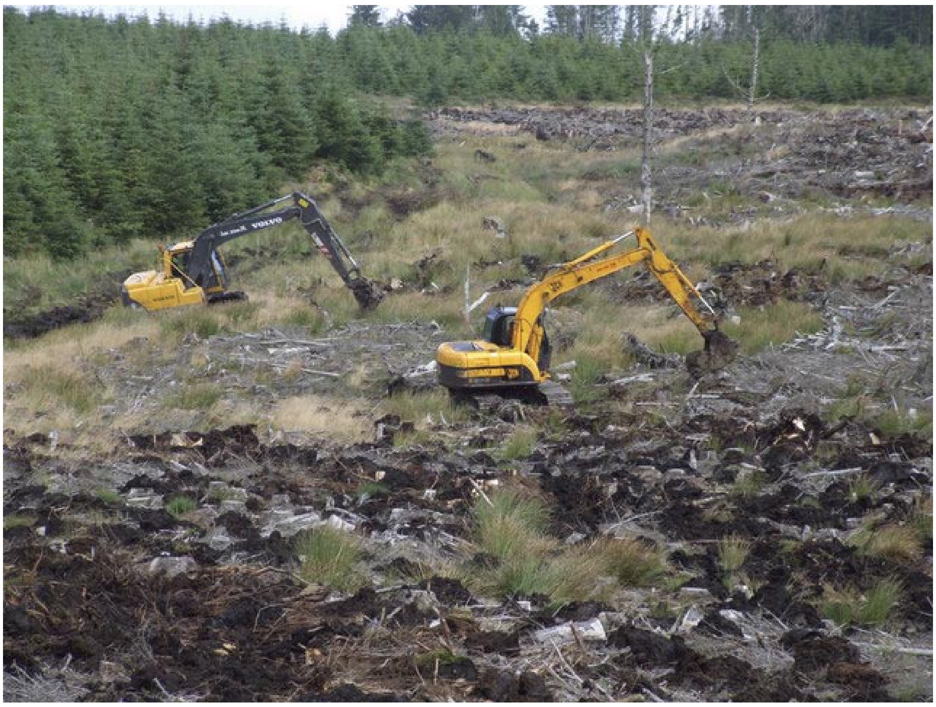
Water and buildings - what should we measure and manage?

So, if we don't need to worry about the water footprint of our building materials per se, do we need to worry about water in relation to the construction industry at all? There are several obvious areas of concern.

Whilst in volumetric terms the amount of water used on site during construction is relatively insignificant, there is often considerable risk of local diffuse pollution issues in relation to mud and dust. Simple technical fixes are available. Waterless systems can be used for tyre cleaning as opposed to wheel washing, dust suppression techniques vary enormously in their water use, and temporary roadways on site reduce mud formation and have the added benefit of minimising soil compaction (and therefore decreasing the volume of water that runs off the site following rainfall). The temporary nature of water distribution systems on a construction site can mean that relatively little attention is paid to leaks and positioning of stop valves, despite the potential to save water.

In terms of timber products, the water footprint is not a useful metric. Meanwhile, forests (both natural and planted) play a vital and complex role in hydrological cycles, and the way in which forestry is managed can have an enormous impact on the local environment.[13] Poorly constructed access tracks and culverts draining them can increase surface water runoff and the risk of flooding events, and felling and planting operations can also have enormous soil erosion and water quality impacts due to vehicle movement. The FSC (Forestry Stewardship Council) requirements include several that relate to water quality management, so this provides a good starting point.

It is difficult to make generalised statements about the water impacts of producing building materials because of the disconnect between volume consumed and environmental impact discussed earlier - all it is really possible to do is to insist that the building product has been manufactured in a country with a relatively well developed



In forestry, poorly constructed access tracks and culverts draining them can increase surface water runoff and the risk of flooding events, and felling and planting operations can also have enormous soil erosion and water quality impacts due to vehicle movement. The FSC (Forestry Stewardship Council) requirements include several that relate to water quality management, so this provides a good starting point.

governance regime for the environment, which therefore manages both abstraction volumes to encourage water efficiency where necessary, and discharge limits to control local aquatic pollution from the manufacturing industry. In the future, the incorporation of better water data into LCA studies should allow a more quantifiable metric to be developed in this area.

Numerous other metrics and reporting initiatives exist beyond the water footprint, including tools aimed at business risk (e.g. the water risk filter by WWF),[14] stewardship initiatives and reporting standards (e.g. the Carbon Disclosure Project has a water standard).[1] Of these, the most useful in relation to the construction industry are initiatives such as the Alliance for Water Stewardship[16] which indicates industry and location-specific measures, so for example would include the impact of poor forestry practices on local water quality, or the extent to which water withdrawals for a production facility were minimised.[17] A degree of harmonisation of these certification systems and an increase in the number of products certified is likely to take place in the near future.

Having contemplated water footprints for several years, I am convinced that we should focus on the 'use phase' of a building and not overly concern ourselves with the water footprint of the 'construction phase'. The message for environmentally aware builders and architects therefore remains the same as it has been for the last 10 years or so; specify water efficient appliances, be mindful of the fact that saving hot water is far more important than saving cold, retain a sense of perspective on the relative importance of the environmental problems we face, and if in doubt, interrogate the numbers.

Judith Thornton

1. Discussed at length in Allan, T. (2001) The Middle East Water Question: Hydropolitics and the Global Economy, London: Tauris.

2. Whilst the prospect of 'water wars' is a common topic for journalists to get excited about, the evidence to date suggests that nations are more likely to co-operate over water than to go to war over it. Is it simply too important to fight about? www.transboundarywaters.orst.edu/database/DatabaseIntro.html

3. The approach to calculating water footprints according to the WFN method is detailed in the (freely downloadable) Water Footprint Assessment Manual. Hoekstra (2011). www.waterfootprint.org

4. Orr & Chapagain (2008). UK Water Footprint: the impact of the UK's food and fibre consumption on global water resources. WWF.

5. Reviewed by Kounina et al (2013). Review of methods addressing freshwater use in life cycle inventory and impact assessment. Int J LCA 18(3). 707-721.

6. A further complication is that the definition of consumption itself varies; the International Water Management Institute (IWMI) definitions are the most widely accepted, and are detailed in Perry (2011). Accounting for water use: terminology and implications for saving water and increasing production. Agricultural Water Management 98 (12). 1840-1846. These differ from the WFN definitions, outlined in the Water Footprint Assessment Manual.

7. As an example (for a combined-cycle gas turbine). A once through cooling system would require approximately 48 litres/kWh water abstracted, of which just 0.4 litres/kWh is consumed. In contrast, a CCGT with an indirect cooling system would require just 0.9 litres/kWh abstracted, of which 0.7 litres/kWh is consumed.

8. This bears no relationship at all to the concept of household 'grey' water (generally defined as the wastewater derived from a household, with the exception of WC flush water).

9. Environmental input-output analysis (EIO). Input-output analysis is a technique in which each sector of an economy is represented as a row and column in a table, with the data in each cell constituting the output of that sector to every other sector. Environmental information (such as water withdrawals) for each sector can also be added to the table, thereby allowing the inter-dependencies of sectors to be understood and their reliance on environmental resources to be studied. Based on work by Wassily Leontief, for which he won the Nobel prize. Reviewed in Leontief (1970) Environmental Repercussions and the Economic Structure: An Input-Output Approach. The Review of Economics and Statistics, 1970. 52(3): p. 262-271.

10. Draft International Standard ISO/DIS 14046.2: Environmental Management - Water Footprint - Principles, Requirements and Guidelines (International Organization for Standardization, 2013).

11. Discussed in their excellent book - Balancing water for humans and nature: the new approach in ecohydrology. 2004: Earthscan.

12. The separation of water into green and blue has led to some policy makers believing that green water is effectively free - the result is an increasing number of closed river basins, caused by increasing efficiency of small scale capture of green water and so a lack of groundwater recharge and hence streamflow downstream. An excellent example is Ramgarh dam in Jaipur - built to serve the needs of the city and with a capacity of 75 million m3 it has been completely dry owing in large part to initiatives to increase agricultural water efficiency upstream.

13. Calder (2007). Forests and water - ensuring forest benefits outweigh water costs. Forest Ecology and Management 251: 110-120.

14. WWF and DEG. The Water Risk Filter. Available from: http://waterriskfilter.panda.org/Default.aspx.

15. Collective responses to rising water challenges, 2012. www.cdp.net/en-us/programmes/pages/cdp-water-disclosure.aspx

16 www.allianceforwaterstewardship.org

17. The European Water Stewardship initiative (http://www.ewp.eu/activities/ews/) dovetails nicely with the requirements of the European Water Framework Directive, although as with many voluntary certification schemes, companies only choose to apply for certification if they know they will reach a 'gold' standard.

Judith spent 18 months pondering water footprints at the University of Leeds, but recently escaped back to Wales and is now based at the Institute of Biological, Environmental and Rural Sciences (IBERS) at the University of Aberystwyth. Prior to that she spent time at the Welsh School of Architecture in Cardiff, and the Centre for Alternative Technology, Machynlleth.