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A Nuffield Farming Scholarships Trust Report

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Sustainable Water Use: Opportunities for Agriculture Based on Cross Disciplinary Knowledge Sharing

Dr Tom Young

October 2023

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A Nuffield (UK) Farming Scholarships Trust Report

Date of report: September 2023

"Leading positive change in agriculture. Inspiring passion and potential in people."

Title	Sustainable Water Use: Opportunities for Agriculture Based on Cross Disciplinary Knowledge Sharing
Scholar	Dr Tom Young
Sponsor	Worshipful Company of Gardeners
Objectives of Study Tour	Observe a variety of methods and technologies used to reduce water consumption, use water more efficiently and source water from alternative sources. Understand common barriers preventing uptake of these methods and technologies in different industries, and potential solutions for overcoming these barriers in the UK.
Countries Visited	UK Greece Israel USA Canary Islands Spain Singapore Australia New Zealand
Messages	• The UK will experience water stress on a much more regular basis in the future, particularly in the South and East. • Agriculture, horticulture, amenity, and landscape are all vulnerable to water shortages and need industry-wide change to become water secure. • Multiple solutions exist to improve UK water security. • These include alternative water sources, technology to improve irrigation, catchment wide land management, as well as empowering and supporting local water groups. • The UK must change its management of water to adapt these alternative approaches. The current system is too restrictive for innovation and change.

Executive summary

The agricultural, horticultural, amenity and landscape sectors all require water. However, the UK's water resources are becoming increasingly stretched, especially in the South and East of the country. UK water security is now a real concern. Water security is a key challenge for any country and is defined as the ability to provide a resilient water supply for all users in the long term. Other countries such as US, Australia, Israel, Spain and Singapore are more experienced than the UK at dealing with water shortages and have developed multiple solutions to become water secure.

The main aim of my study tour was to visit countries which have already experienced significant water stress, and therefore have been forced to develop solutions to the problem.

Alternative water security solutions observed on my travels included use of treated wastewater either directly or to recharge ground aquifers; large scale rainwater harvesting; use of satellite and sensors to inform irrigation regimes; water efficient irrigation such as sub-surface drip; crop breeding to improve water efficiency; desalinated water; supply chain water resilience management; and holistic landscape level soil management.

All these solutions have multiple barriers preventing their uptake in the UK. These are universal with other countries and industries. These include financial risk of investment; stakeholder resistance to change; lack of industry knowledge on alternative technology; regulation restricting innovation; challenges of inter-disciplinary working; and a low support for long-term planning.

However, I observed many examples of stakeholders overcoming these barriers to implement water resilient projects. Prevailing patterns among these success stories include stakeholders driving projects forward; support and long-term planning from government; inter-disciplinary working; and local ownership of problems.

Given the complexity of the issue, addressing the issue of water security in the UK demands a multifaceted approach. None of these solutions will be straightforward to implement and will necessitate significant shifts in our perspectives and long-term strategies for the management of water resources.

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DISCLAIMER

The opinions expressed in this report are my own and not necessarily those of the Nuffield Farming Scholarships Trust, or of my sponsor, or of any other sponsoring body, or of my employer. All images taken by Tom Young unless otherwise stated.

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1. Personal introduction

I have always been fascinated by natural processes and how they interact with one another. Therefore, it was an obvious choice to study a degree in ecology at the University of Sheffield. I enjoyed the ecological nature of my degree, but always wanted to be practically involved in projects. Therefore, I chose to focus on applied research in my industry-sponsored PhD in green roof substrate research. The applied nature of this research appealed as it let me to make a difference in the 'real world'.

However, I was frustrated by the slow transfer of knowledge between academia and practitioners. Research could be significantly improved if interaction with industry occurred at an earlier stage. A greater understanding of how industry works is needed in academia.

In 2014 I left academia and have worked as an applied research and environmental consultant in the amenity and landscape sector for the last nine years. I work with clients on a wide range of projects from designing roof gardens; integrating drainage water into landscapes; designing innovative irrigation systems; and integrated water management strategies. These projects have made me realise that water security is a universal problem in amenity, landscape, horticulture, and agriculture. Solutions to these problems exist across all industries, with a vast knowledge bank present among practitioners. However, this knowledge is often siloed, or very industry specific.

A Nuffield Farming Scholarship has given me an opportunity to look at the topic of water from a multi-disciplinary perspective to gain insights from different industries and countries. The solution to this very complex problem won't be found in my Nuffield report, but I hope to be able to provide a useful document to help advance innovative water management in the UK.

2. Study tour background

Water is a hugely unifying resource. All agricultural, horticultural, amenity and landscape industries require it in some form or another. The UK enjoys a temperate climate which provides large amounts of rainfall spread throughout the year. This has given rise to the adage of England being a 'green and pleasant land' which is certainly the reputation in other countries. However, due to its geography, the rainfall in the UK is very uneven, with huge amounts falling in the West of the country, and relatively low amounts in the East. Water resources in the East and South of England have been stretched for several years, with rainfall in my home county of Huntingdonshire actually at the same level as Tel Aviv, Israel.

This trend is being compounded by extreme weather events driven by climate change, increased demand, environmental requirements and increased leaks from ageing infrastructure (Environment Agency 2020). These all combine to affect the UK's water security, which is defined as the ability of a country to maintain a resilient water supply for all users in the long term.

Recent extreme climate events have brought the issue of water security to the forefront of the public's attention. Practitioners are now being restricted in water use through greater scrutiny of abstraction licences and less access to potable mains water (Environment Agency 2020). In a survey of water industry professionals conducted as part of this study, 76.6% listed water shortages as one of the most important future threats to the industry, and 87.2% climate change.

Despite this, the UK lags behind other countries in its approach to water security. It is still not taken seriously as a national resource problem and political apathy exists when it comes to long-term and holistic water management. This is in part driven by the huge scale of the problem, and multiple players who are needed to be involved to drive change.

Technical and behavioural solutions exist that can help the UK improve its long-term water security. These are available and should be integrated into a UK long term water management strategy. The UK is still at an early stage in its water security journey, and therefore much can be learnt from countries who have had to deal with water resource issues for a much longer period.

The main aim of my study tour was to visit countries which have already experienced significant water stress, and therefore have been forced to develop solutions to the problem.

3. My study tour

Table 1: Tom Young Nuffield Farming Scholarship Study Tour 2022-2023

Date	Country	Timing	Venues/Practitioners
2022-2023	UK	7 days	Felixstowe Hydro Cycle Binsted Nurseries Stephen Briggs, NSch The London Golf Club Castle Course, St Andrews UK Irrigation Association (UKIA) Conference 2022 & 2023 Fresh 4C's Conference 2022
2022-2023	Online Meetings	1-2 hours in length	Various practitioners in the UK water industry Seawater Greenhouses NFU Good Stuff International
June 2022	Greece	2 days	Stavros Niarchos Green Roof Dr Nikolaos Ntoulas – green roof researcher
July 2022	Israel	5 days	Netafim Research Site Gilat Research Centre Volcani Institute Ramat Ha Negev R&D Centre Agamon Hula Wetland Beersheva Lake Park
September 2022	USA (California, Arizona, Colorado, Iowa)	14 days	CNRA CERES Biosphere 2 & various Native American sites Central Arizona Project Des Moines Water Works Truterra Orange County Ground Water Replenishment System Kathryn Sorenson – Kyl Centre for Water Policy Anne Castle – Ex Federal Government Ruth McCabe – Heartland Co-Op
December 2022	Canary Islands	5 days	Nieblagua – Fog Harvesters La Caldera Finca Hydroponics Barrancovergara Banana Plantation David Riebold – local expert in traditional dry farming EU LIFE reforestation project
January 2023	Spain (Barcelona, Murcia)	5 days	Camiral Golf Course Eixverd – green roof company CREAF CEBAS Marcela Munoz - BION
March 2023	Singapore	3 days	Public Utilities Board – National Water Company Green Infrastructure sites throughout city
March 2023	Australia (Melbourne, Canberra)	9 days	Melbourne Water Mulloon Institute Green roof practitioners Dr Joerg Werdin Yarra for Life Project University of Melbourne E2 Design
March 2023	New Zealand (South Island)	11 days	New Zealand Nuffield Triennial

4. Water security solutions

I observed multiple water security solutions on my travels. This section summarises them to highlight methods which will be important for future UK water security.

4.1 Water demand reduction

4.1.1 Sub-surface and drip irrigation

Drip irrigation systems emit water locally via controlled drippers directly to the soil on the surface or below ground (Fig. 1). This allows water to be delivered directly to plants, reducing evaporative losses, and potentially reducing water demand by between 25-50%.

Case Study: Netafim Research Centre

Israel has been a world leader in alternative irrigation systems, with several international companies based in the country, including Netafim. Although the concept of drip irrigation is simple, the emitters themselves are the result of years of research and development to ensure even water distribution and longevity in the field. The use of treated wastewater, which is often high in nutrients, can quickly lead to the build-up of biofilms within pipes and emitters. Therefore, Netafim have conducted a large amount of research to create self-cleaning emitters which use a fluctuating flow to prevent biofilm build up and increase the longevity.

Case Study: Wroot Irrigation UK Potato Farm

Currently there are only a few examples of sub-surface agricultural irrigation in the UK. A previous Nuffield Scholar, Anthony Hopkins of Wroot Water, showed me an installed potato farm system. The system was installed 30 cm below the surface in light sandy soils and will be removed after the crop harvest and recycled (Fig. 2). Initial feedback showed increased crop yield and reduced water use.

Figure 1 - Permanent drip irrigation under a plastic mulch in a citrus fruit orchard in Israel

Figure 2 – Temporary drip irrigation system installed in a potato crop in Lincolnshire, UK by Wroot Irrigation.

4.1.2 Agri-Solar

The integration of photo-voltaic (PV) electricity generation and arable crops is starting to gain traction. The integration of the two effectively allows the same land to be used twice, with power generated, and crops/livestock hosted. Water can be harvested from the PV panels and stored for later use, or water demand can be decreased due to the shading provided by the panels.

4.1.3 Sensors and satellite imagery

Many companies now offer sensor systems for agriculture, horticulture, landscape and amenity, with physical sensors either permanently installed or used for spot checks. For larger sites, satellite or drone imagery can be used to supplement ground measurements. This data is used to monitor soil and crop moisture levels. Advanced systems integrate this data into irrigation systems to manage irrigation cycles. This can save significant volumes of water though targeted irrigation, especially when used in combination with accurate irrigation systems.

Case study: Swan Technologies

Swan Systems are a Agri-tech service provider and consultant. Set up by Tim Hyde, a famer and agricultural consultant from Australia, with the aim of reducing a user's workload. Swan acts as an irrigation optimization tool which still requires user input to optimise outputs (Swan Technology 2023). Swan have found that hardware (sensors on the ground) is unreliable and so have a remote based system. This takes data from multiple sources and packages it together for the user with recommended irrigation cycles. The user can then choose to use these or generate their own, with Swan Technologies still involved as traditional agronomic consultants alongside the tool. It is estimated that this approach can reduce irrigation by up to 30%.

Case Study: Castle Golf Club, St Andrews

The greenkeeping team at the Castle Course, St Andrews spent six months observing, adjusting, and repairing every single irrigation head to ensure optimal water distribution. An innovative GPS enabled moisture probe was also used multiple times a week to monitor water distribution through the soil, to further optimise subsequent irrigation cycles. This is estimated to have reduced annual irrigation demand by 5% and resulted in improved agronomic performance.

4.1.4 Crop breeding and genetics

A large area of agronomic research is focusing on improved plant resilience to drought.

I spoke to Catherine Preece at CREAF who is researching exudates from different crops (types and age) in response to drought. Root exudates are a range of compounds released into the soil, and can help with nutrient and water uptake, and drought resilience. Initial findings have shown that older variates of crops may release different types of exudates, and these could be utilised to help develop more water-efficient plant breeds. The breeding cycle of crops can now be sped up to improve certain characteristics. Other methods of improving drought tolerance in crops include mycorrhizae fungi inoculation and application of plant growth regulators.

4.2 Alternative Water Sources

4.2.1 Wastewater reuse

The most common alternative water source I observed on my travels, and the one most underused in the UK, is treated wastewater, or treated sewage effluent (TSE). This is the effluent discharged from sewage treatment plants, but can also include 'greywater', which is drainage runoff and domestic water from cleaning. In the UK sewage water is tertiary treated, meaning it undergoes three separate stages of treatment. This removes solids, kills bacteria, and reduces nutrients to below set levels. This is often discharged into water courses for further dilution. In a Nuffield online survey of water professionals, 85.1% of respondents felt that reuse of wastewater was either a good, or very good idea, showing that that the concept is universally approved by professionals in the water sector (Appendix A).

TSE water often has elevated nutrient levels which can be advantageous for crop growing, although associated salt levels mean that care must be taken when applying. Using wastewater can help alleviate several wider environmental issues, including reducing nutrients entering watercourses, improving soil organic matter, reduced reliance on potable water and use of synthetic fertiliser. However, care needs to be taken when using these resources, with elevated salt levels, potential contaminants building up in soil and public health issues important considerations.

In countries with water security issues, wastewater is seen as a resource, particularly for non-potable uses such as agriculture. The term 'wastewater' is not actually used in these countries, with 'recycled', 'treated' or 'reclaimed' used.

Case Study: Israel National Water Supply

Israel was the first country to fully embrace treated wastewater. This was partly out of necessity in the 1980s, with lakes and aquifers becoming brackish due to over abstraction and sewage discharge. Competitive pricing, as well as volume caps for potable water was used to quickly move agriculture onto this new supply, with around 80-90% of crops now irrigated with this water.

An extensive research programme was set up in the country's agricultural research centres. These started to pick up increased levels of salt in soil and fruit 5-10 years into the programme (Fig. 3). Various methods were developed to help mitigate against this, including salt resistant root stocks, mulches to reduce evaporation, irrigation drippers, flood irrigation to flush and localised desalination. From 2008 the country also started to produce a greater amount of desalinated water. The increase of desalinated water in the country's supply decreased salt levels in wastewater and therefore, indirectly helped to solve this issue. In fact, the lack of magnesium in supplied wastewater now requires some farmers to add this back into irrigation water, highlighting the reduction in dissolved slats in the water.

I also observed the use of TSE in public parks in Israel (Fig. 4). Amenity lakes which use this water were still accessible to the public but had warning signs attached on the risks associated with the water. This helps to directly educate the public about alternative sources of water.

Figure 3 – Citrus fruit wastewater trials at Gilat Research Centre Volcani Institute, Israel.

Figure 4 – Use of treated wastewater in Iasrael public parks with warnings signs.

Case Study: Spain, Murcia – Blending Technology

Dr Francisco Pedrero Salcedo at CEBAS in Murcia, Spain has researched solutions for using poor quality wastewater. This measures water quality as it enters a site and then blends it with other water sources to create a mix that meets preset criteria. Easy to use and cost-effective systems which measure water quality 'live' and then make instant changes to water blends have been designed. The trial farm at CEBAS is also used to showcase the technology to potential users to allow them to experience it before installing it, dramatically increasing confidence in technology and wastewater.

Case Study: Australia, Melbourne – Western Wastewater Treatment Plant

The most impressive reuse of wastewater I observed was at the Western Wastewater Treatment Plant in Melbourne, which has a farm onsite (Fig. 5-6). When the site was set up at the start of the 20th Century, primary treated wastewater was pumped onto fields and left to settle. The process is now much more advanced, with a series of settling lagoons, treatment areas and sterilisation UV used prior to water being discharged to the farm. Lagoons are even covered to capture methane produced by the effluent and used to power the site. The site now provides too much water for the farm to use, and so water is also supplied to the local horticultural industry.

Figure 5 – Western Treatment Plant farmland, Melbourne Water, Melbourne Australia.

Figure 6 – Western Treatment Plant settling lagoons, Melbourne Water, Melbourne Australia.

4.2.2 Groundwater recharge

Groundwater or managed aquifer recharge (MAR) is increasingly being used as an efficient location to store water, for later abstraction. Water can be from any source, although most commonly from treated wastewater or stormwater. The infiltration process is used to further clean water in some locations (Israel), although there are strict rules in other locations (California, Arizona, UK) to ensure that ground aquifers are not polluted by source water.

Case Study: Orange County Ground Water Replenishment System (GWRS), California

Due to an over abstracted ground aquifer, GWRS was set up in Orange County, California in 2008. The facility takes treated sewage water and passes it through a series of osmotic membranes to produce ultra-pure water (Fig. 7-8). This water is then pumped into the ground aquifer for later abstraction.

This helps to reduce reliance on costly imported water from outside the catchment, reduce treated sewage discharge to sea and prevents saltwater intrusion of the aquifer. The facility can produce up to 492,000m^3 a day, and is still being expanded. The system allows Orange County water users to abstract a set volume of water each year, providing each customer uses their allocation sustainability.

Figure 7 – Treatment chambers at Orange County Ground Water Replenishment System

Figure 8 – Osmotic membrane treatment at Orange County Ground Water Replenishment System

4.2.3 Rainwater harvesting

Despite being the simplest of alternative water sources, water harvesting is still underutilised in the UK. Water is collected from hard surfaces across facilities, or from drainage, stored and reused.

Case Study: London Golf Club, London

The London Golf Club was constructed in the early 1990s and uniquely placed water harvesting at the centre of its landscape design (Fig. 9-10). Approximately 90% of the 500-ha site is drained into a series of collection lakes. These cascade into one another and are pumped up into a main 100,000m^3 reservoir. This allows the Club to be self-sufficient for irrigation water.

Figure 9 – London Golf Club water harvesting lake

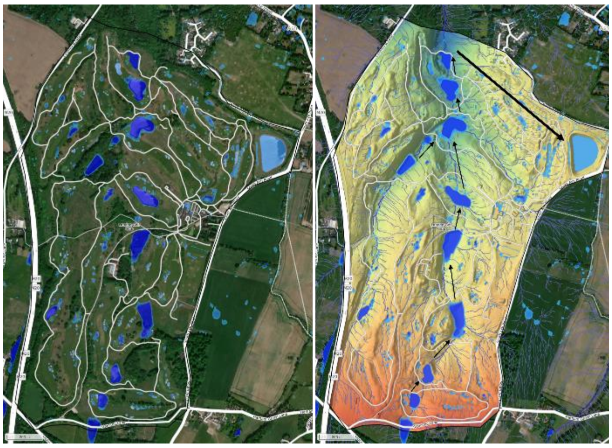

Figure 10 - London Golf Club water harvesting lake system overlayed on topographical map

4.2.4 Fog water

The most unexpected water source I observed was fog water harvesting in the Canary Islands. The islands should have a Saharan climate but, due to the steep volcanic islands and warm coastal air, the islands experience fog 120-140 days a year. The island's native ecology formed 'cloud forests' with tree leaf shape adapted to capturing fog as it moves through the canopy, then dripping it onto the ground, feeding large groundwater aquifers. This allowed large forests to colonise the island but which were removed post human occupation. This affected the natural collection of water, which combined with over-abstraction, led to depleted groundwater supplies.

Case Study: Nieblagua and Life Project

Efforts are now underway to re-establish forest on the mountains, with fog water captured using bespoke fog collectors. Modified tree guards are also being trialled which collect and distribute fog water to the base of trees (Fig. 11). Nieblagua supply fog collectors to farmers on the islands, with one off grid almond farm using twelve collectors to capture enough water to establish a 4000-tree almond grove (Fig. 12).

Figure 11 – Individual tree fog collectors, helping re-establish trees on hillsides in Gran Canaria, LIFE proejct.

Figure 12 – Nieblagua fog collectors on isolated almond farm on Tenerife.

4.2.5 Desalinated water

Desalinated water is increasingly used in arid countries. The production of potable water from seawater has a massive energy cost and can lead to localised environmental issues. However, I observed its key role in many countries providing a significant proportion of water supply. Due to its high production cost, this water is often not used for agricultural irrigation, but can free up other lower quality sources of water.

Case study: Singapore 4 Pillars Water Supply

The long-term strategy of Singapore was the most impressive public policy I observed on my travels. The 4 Pillars of Water or 'National Taps' Strategy (Rainwater, NeWater, Import and Seawater), first developed in the 1970s, aims for Singapore to be fully self-sufficient in water. It has reuse and integrated management at its centre. The development of 'NeWater' or 'used/reclaimed water' which treats wastewater to potable standards has been key.

A high-profile public education exercise has been in place since the early 2000s, highlighting safety and importance of NeWater. The Prime Minister at the time even went on national television to drink the water publicly (Fig. 13). Language is very carefully considered when describing the water product, with words such as 'waste' or 'sewage' no longer used.

The 4 Pillars Water Project is centrally planned and controlled by the Singapore Government, allowing a long-term vision to be realised. The government owned Public Utilities Company (PUB) is tasked with implementing the vision, with support from private companies where needed. The development of technology by PUB was facilitated by the co-evolution of knowledge between public and private sectors, who understood the economic benefits of this sector, with technology now being exported across the world.

4.2.6 Movement of water between catchments

The biggest single infrastructure project I visited was the Central Arizona Project (CAP). Built between 1973-1993, the 336-mile diversion canal takes water from the Colorado River into Arizona. This requires multiple reservoir and pump stations to move the water (Fig 14).

Despite being an extremely controversial project, the system has delivered large amounts of water into the Arizona basin over the last 30 years. However, it loses significant volumes of water via evaporation during transport, depletes Colorado Basin water levels and has experienced issues with high delivered price of water for consumers (Hanemann 2002). Therefore, the system is likely to change its main water source in the future, and potentially reduce how much it provides. Already, agriculture is being encouraged to utilise groundwater supplies and give urban users higher priority to the CAP water. Any leftover water is now used to recharge aquifers as a wider environmental approach.

Regardless of the politics of this project, it provides an example of very large and expensive infrastructure used to solve issue and the potential issues this can cause. A large infrastructure approach can lead to futures issues as the infrastructure needs to be used to justify its cost and may not be flexible in how it responds to changing climate and demand.

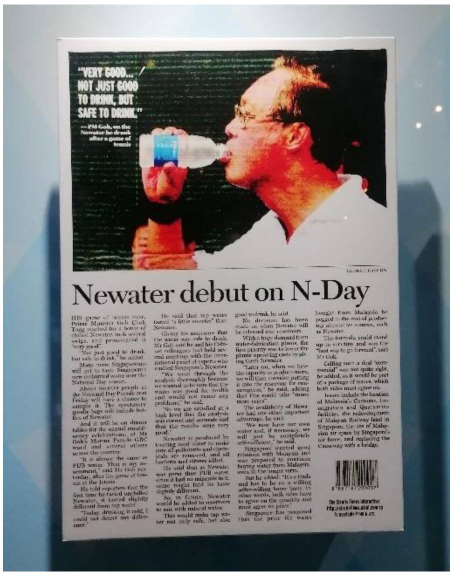

Figure 13 – Singapore Prime Minster seen drinking NeWater to show its safety

Figure 14 – Central Arizona Project (CAP) main water transfer canal in Phoenix, Arizona.

4.3 Integrated water management

4.3.1 Landscape scale

Integrated water management lends itself to a catchment scale approach. Catchments are the building blocks of hydrological systems, and it is logistically simpler to manage water within these systems. Human activity has interfered with natural catchment systems through the implementation of artificial drainage schemes, pumping of water and excessive use. However, within these artificial systems, opportunities exist to repurpose existing infrastructure such as drainage, to create new sources of irrigation water.

Case study: Felixstowe Hydro Cycle project, UK

The Felixstowe Hydro Cycle project is an innovative collaboration between local authorities and farmers. The project was in development for over 10 years and required significant engagement with multiple stakeholders to a) define the local issue (water security for farmers and untapped resources) b) decide on a strategy to deal with the problem c) identify funding mechanisms and d) implement a solution. The solution is technically simple, with current land drainage water intercepted before it is pumped into the sea, then pumped back up to a series of farm reservoirs as well as a demonstration Managed Aquifer Recharge (MAR) site (Figs. 15-16) (Hiscock et al. 2023).

This provides a year-round water supply and helps prevent saltmarsh degradation at the drainage outlet.

Innovation came in the funding and governance of the scheme, which led to a new company funded by the farmers themselves. Farmers then purchase water from the company, providing a return on investment and financial capital for future upgrades and maintenance.

Figure 15 – Abstraction point from existing drainage network for Felixstowe Hydro Cycle project

Figure 16 – Demonstration Managed Aquifer Recharge (MAR) for Felixstowe Hydro Cycle project

4.3.2 Supply chain scale

On a much larger scale, water security at a supply chain level is starting to be seen as a key business security metric. The first stage is mapping a baseline for whole supply chains, and then exposing any risks within this supply chain and therefore to the business. Many companies do not have the expertise or experience needed to develop robust water resilience plans for whole supply chains. Therefore, several companies have expanded to fill this gap.

Case Study: CERES, Good Stuff International (GSI) and Alliance for Water Stewardship (AWS)

CERES operates as a nonprofit advocacy group which work with companies to develop water security plans highlighting the financial risk of water. Companies are required to fully commit to the process to make it successful, with a key metric of success being the seriousness that water is considered by the company, for example making water security a board meeting item.

GSI work more closely within a supply chain, identifying technical solutions that may be available to improve water security. This may involve working directly with producers to develop local solutions, as well as facilitating workshops between suppliers and supermarkets. GSI sometimes use a globally recognised framework for sustainable water use, called AWS. This provides a framework for users to identify issues, develop and implement a plan, and then evaluate to improve.

4.4 Holistic land management

Water management is intrinsically tied to land management. Intensive land management disrupts natural hydrological cycles through increased runoff, lower levels of infiltration and land erosion. When managed correctly, landscapes help to mitigate against these impacts (known as ecosystem service provision). Integrated land management can help a landscape absorb more water, prevent potential flooding downstream, increase local water availability and help recharge aquifers.

Case Study: Mulloon Institute

The Mulloon Institute is a non-profit research institute originally set up by Anthony and Toni Coote because of their experience of sustainable land management on their farm. This involved improving resilience, productivity, and profitability of land by rehydrating it through multiple leaky weirs to slow and manage flow. These weirs slow sub-surface flow from surrounding land into water courses, helping to return them to natural year-round flow, as well as creating important habitats (Figs. 17-18). To make a large impact across a whole catchment, 23 landowners were involved. The project now conducts detailed research to provide evidence of its approach, writing its own code of practice and lobbying government to make it simpler for landowners to replicate this model.

Figure 17 – Leaky weir installed on a previously degraded river network at Mulloon Institute, Canberra Australia.

Figure 18 – Restored River channel showing landscape hydration and vegetation re-establishment due to water management Mulloon Institute, Canberra Australia

5. Barriers to solutions

A common theme discussed with practitioners was the many barriers they face when trying to implement water security solutions.

5.1 Technical challenges

Innovation requires new technology or methods to be implemented, which can be seen as a risk until proven in the field.

5.1.1 Financial Cost

The most common barrier experienced was the upfront financial cost of installing new technology, and the short/long-term financial pressure this places on the business.

I saw plenty of examples where this risk was mitigated against using government grants or schemes. However, stipulations and restrictions often accompany these, making them less attractive.

- The Felixstowe Hydro Cycle project received grant money. One stipulation was to test an innovative MAR system. However, the amount of environmental testing required to install this system meant this section of the project cost far more than expected.

5.1.2 Unintended consequences

Altering established systems can often have unintended consequences for the user. This may give new ideas bad reputations, increase government restrictions, and reducing future uptake, unless technology/policy can be dynamic and show that issues are being resolved.

- The rapid uptake of TSE for agricultural irrigation in Israel resulted in a sudden increase in the amount of salt in soil. Another innovation (desalinated water) started to dilute this effect and reduced its impact. The whole system was monitored by a network of government funded agriculture research facilities which picked up this trend before it became an issue.

5.1.3 Technology development

Technical development takes time, money and failures before it is commercially available. This requires early adopters who are willing to take risks. This can put users off unless financial incentives help de-risk projects (Posthumus et al. 2008). In other cases, technology required to solve a particular problem may not exist yet, requiring users to make alternative, or longer-term plans. For example:

- Singapore wanted to clean and reuse wastewater in the 1970s. However, desalination technology did not exist at the time to make this viable. Singapore did not change its long-term version but extended its timelines to when desalination technology became cost effective.

5.2 Governance

5.2.1 Regulatory

Often environmental regulations designed to protect the environment can themselves be a barrier to scheme implementation (Speight 2015). On the surface this might appear to be a contradiction, but very specific legislation, for example individual species protection can significantly delay environmental projects if they are found nearby. Blanket legislation such as restriction to river channel modification, regardless of current ecological condition, can mean projects require significant surveys to prove they will not further degrade habitats.

For example:

- The Mulloon Institute has been lobbying government to change legislation, so channel modification designed to improve river condition and base flows does not require costly surveys before implementation. This is based on a requirement to follow detailed guidance in a recognised code of best practice written by the Institute (Peel et al. 2022).

5.3 People

5.3.1 Public and practitioner perception

Perception of new technology/methods is key to successful uptake. A major mistake when pushing change can be to force change without gaining full buy in from stakeholders (Hewett et al. 2020).

- Mandatory introduction of wastewater for fruit growers in the south of Spain due to aquifer depletion was introduced without consultation or demonstration of proposed technology. This was met with backlash from growers and required multiple retrospective education events and an early adopter demonstration farm to alleviate concerns.

5.3.2 Integrated cross disciplinary working challenges

Working with multiple stakeholders from different disciplines is a challenge. Water use falls very firmly into this category, with integrated water management involving professionals, end users and government departments across all disciplines. What may be seen as beneficial for one group, may be detrimental for another. Technical language used in these conversations can be a major barrier, with time needed to create common reference points and definitions. It is also logistically hard to regularly organise large numbers of people into the same spaces to make real long-term connections. For example, CNRA in California has responsibility to engage with over 2,300 entities.

5.3.3 - Long term thinking

A common human trait is the inability to plan properly for the long term (O'Donnell, Lamond, and Thorne 2017). This is especially true in integrated resource management, which requires a multi-generational approach with multiple stakeholders. In conventional democracies, it is also very hard to sell large, long term and expensive, national plans which may not show benefits for several election cycles. Ultimately water resources go beyond individual ownership and use, which requires skilled and strong leadership to ensure planned long term thinking (Bernhardt et al. 2006).

Concern about national security is one driver which seems to empower real long-term thinking. However, in many of the countries I visited, water security only becomes a national issue during stress periods and is soon forgotten about unless pressure remains.

- Israel's national water infrastructure allowed for agricultural expansion in the 1950-60s. Israel still benefits from the initial designers' foresight, which allowed for adaptation and expansion.
- Singapore set itself the goal of being water self-sufficient by 2050. It will reach that target well in advance through a national led infrastructure programme. A stable national government has allowed this plan to remain a central policy over multiple election cycles.

6. Discussion – innovation and change – how to make it happen?

The case studies presented are a demonstration of what can be achieved, despite some unresolved obstacles. I've observed recurring patterns where practitioners effectively navigate and solve these challenges.

Innovation mindset

A central person or organisation at a local and national level prepared to innovate is key to drive projects forward in the long term. Without key actors who are prepared to innovate, projects can quickly lose momentum and direction. For example, the Mulloon Institute have consistently gone against conventional land management and are now writing best practice guidance. I also saw this innovative approach in the Canary Islands, where a fog harvesting equipment supplier created an exclusive gin brand to advertise the technology (Fig 19).

Necessity

Necessity (natural water scarcity through drought or harsh climate) forces practitioners to change and adapt. For example, traditional winemaking and vegetable growing on the uplands of Lanzarote used a bespoke volcanic rock mulch and crescent shelter system (*Picón*) pioneered in the 19th Century after volcanic eruptions to reduce water losses and allow grape production in a harsh climate (Fig. 21).Furthermore, a sobering example of the effects of shifting climate were observed at historic Native America sites in Arizona, which were abandoned due to lack of water in the 1400s (Fig. 20). These areas were then resettled, and historic water channels reused in the 1880s. This area is now once again experiencing extreme water shortages.

Israel and Singapore are two countries which actively improved their water security due to national security fears. This resulted in the issue being taken seriously by government and the public, justifying large national infrastructure projects.

Balance of government support

I started my travels with the assumption that more government support always helps management of water. I still broadly hold this view but have seen that the reality on the ground is more nuanced. It is apparent that the right level of government support is needed for long term buy in.

This was most evident in the US where Federal Government walks a tightrope of only being involved in State matters when needed. This is required in the Colorado Catchment which has a very complex usage model. Federal government has used the carrot and stick to help stakeholders find common solutions, with the carrot being financial and logistical support, and the stick being Federal restrictions if States do not broker a solution themselves. Government financial support is often only for a limited period. Projects need a regulatory regime that encourages innovation and provides additional support to allow project solutions to continue after funding is no longer available.

Ownership of problem

Although a national issue, impacts of water scarcity are experienced at a local level. This is also the level at which solutions make a real impact. Therefore, it makes sense to allow local water groups to take ownership and find solutions that work for them. This greatly increases the chance of successful independent long-term solutions.

Interdisciplinary working

Water resource management requires input from multiple sectors (Bernhardt et al. 2006). However, the water sector is still very siloed. Interdisciplinary working is becoming increasingly common in the land management sector. Training across all career stages is needed to educate practitioners on the benefits and requirement to use this approach. Individual disciplines still need to be respected, but it shouldn't be that one discipline can take precedence without consideration of alternative approaches.

Social science involvement

In an engineering dominated world such as water infrastructure, social sciences are often not considered. However, when developing new joint solutions, an understanding of how these may be perceived and used by end users is extremely important (O'Donnell, Lamond, and Thorne 2017). Getting long term user and community buy in should be a key aim of any water security initiative. Without it, projects can be inappropriate for the end users, and less likely to have a long-term impact.

Figure 19 – Innovative use of fog water to create a high-end gin brand to promote technology

Figure 20 – Casa Grande ruins, Arizona, USA. The native American people left this area due to changes in water availability approximately 550 years ago.

Figure 21 – Viticulture on Lanzarote, using *Picón* mulch method and wind breaks to allow grape cultivation despite extremely low rainfall.

7. Conclusions

The UK faces huge challenges through increased demand, lower availability of traditional water sources and unpredictable climatic events. These restrictions are already present in the South and East of England and are likely to become more widespread across the UK.

The agricultural, amenity, horticultural and landscape sectors are all heavily reliant on secure water sources for long term security. Water demand from these sectors will increase, and therefore efforts need to be taken to ensure long term security of water supplies.

These sectors are uniquely placed to act as pioneers for good water security practice. They also have no choice but to act decisively. In the future, traditional ground and water course sources may not be available for agriculture and horticulture. Landscapes need to be designed for future climates or risk becoming irrelevant, whilst amenity is likely to be first to undergo restrictions due to its 'non-essential' status. I observed multiple solutions to the UK's water issues that could be implemented:

- Wastewater reuse, as a lower quality resource, or after additional treatment/blending.
- Alternative irrigation techniques such as sub-surface and drip irrigation.
- Use of satellite imagery and sensors to improve irrigation.
- Rainwater and fog water harvesting on a landscape scale.
- Groundwater recharge to increase groundwater supplies.
- End user and supply chain pressure.
- Integrated land management to improve soil water management.

All these solutions are specific to local areas and their circumstances. A mixture of government, NGO and private sector support will be required to ensure such schemes are sustainable in the long term. However, there are a number of barriers that need to be overcome to ensure success:

- Financial cost of infrastructure implementation.
- Long timeline of technology development.
- Current restrictive environmental legislation preventing innovation.
- Public and practitioner lack of knowledge and trust of new technology.
- Lack of integrated inter-disciplinary working experience and long-term thinking.

Solutions to these barriers do exist. Many of these require a shift in the UK's relationship with water:

- Fostering and encouraging individuals that have a water innovation mindset.
- Provision of government support. This does not always have to be financial.
- Change mindset to make water security a significant political issue.
- Promotion of inter-disciplinary water sector working.

Current predications of future UK water supply paint a bleak picture. There is a huge opportunity to change the UK's relationship with water and bring it to the top of the political and social agenda. Multiple solutions already exist that could be used to ensure UK water security. The biggest change needed is the mindset of users, legislators and consumers. 'Normal' water management needs to be very different in the future.

8. Recommendations

Due to the complexity of the issue, multiple solutions exist for dealing with the UK's water security problem. None are easy to implement and will require extensive changes to the way we manage water.

- Make water an issue of national importance and high on the political agenda.
- Water management should be a key topic on the national curriculum.
- Alter the Environment Agency's role to be solely environmental protection enforcer so it can concentrate on this remit.
- Creation of a catchment management led government body tasked with water management at catchment scale. This will bring together all aspects of water management into an integrated unit supporting stakeholders through any development process.
- Increase amount of funding and technical support to help de-risk water infrastructure projects.
- Promote alternative water sources such as wastewater. Fully support the uptake of these by offering competitive pricing structures and reduced bureaucracy for suppliers.
- Continue to develop natural capital private finance markets.
- Promote interdisciplinary resource management as a discipline in its own right.
- Make it a requirement that specific sector has a drought and water security management plan, and new facilities have to consider water security as part of the planning process

9. Post study tour

During and post my Nuffield travels I have become involved in several projects which have directly benefited from my Nuffield travels.

- I have led and assisted with multiple outreach activities with my Sponsor, The Worshipful Company of Gardeners. This involved designing and developing a bespoke water security card game which educates students on the potential and benefits of integrated water management. I have plans to turn this into a digital version, as well as a more developed board game, with several water companies showing interest in collaborating on it.
- I am honoured to be invited to become a member of the Worshipful Company of Gardeners.
- I am now a serving member of the Worshipful Company of Gardeners Schools Outreach Committee.
- I have become a member of Chartered Institute Water and Environmental Management (CIWEM) water reuse working group and am working towards my own Chartership.
- Worked with a water company to identify wastewater reuse opportunities in the amenity sector.
- For my employer, TEP I am involved in a variety of relevant projects including:
    - Multiple UK golf courses to identify alternative water sourcing opportunities to improve long term water security.
    - A well-renowned botanic garden to identify alternative water sourcing opportunities.
    - Advice to UK sporting associations on water security projects.

10. Acknowledgements

I must firstly acknowledge the persistence and energy of Stephen Bernard from the Worshipful Company of Gardeners who strongly encouraged me to apply for a Nuffield Scholarship originally. Initially sceptical, I was soon won over when reading about the amazing opportunity a Scholarship provides. Stephen Bernard, and other members of the Company, provided valuable input into my application and support throughout my Scholarship.

The Worshipful Company of Gardeners have proved to being an excellent and involved sponsor, for which I hope to give back in outreach and Company events. I sincerely hope to carry this on post Nuffield submission.

A big thank you must go to my Nuffield cohort aka 'The Dollars' without whom this experience would not have been the same. We have been lucky enough to be placed in a like-minded and fun group who are always ready to help and advise each other.

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All photos taken by the author.

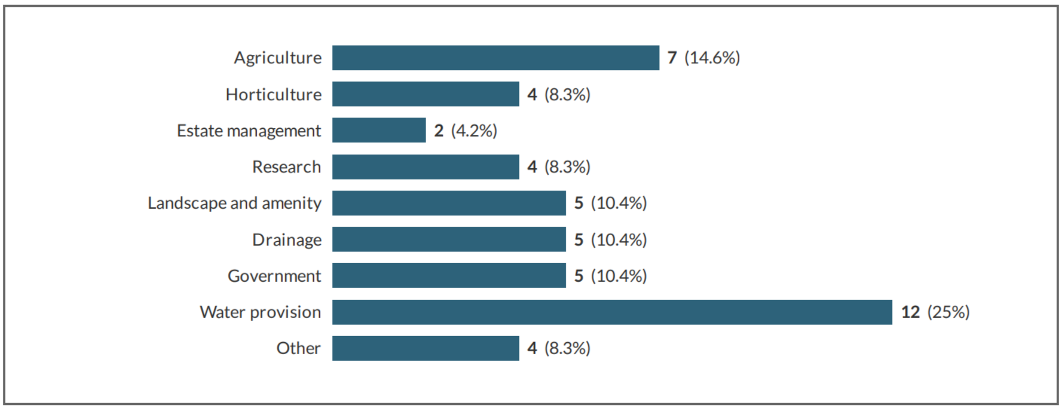
12. Glossary

Term	Definition
Agriculture	Sector responsible for production of crops and animals
Amenity Industry	Sector responsible for maintenance of green space, grounds care, arboriculture and landscaping
Aquifer	A body of rock which holds groundwater
CERES	Private company who promote sustainable leadership among investors, companies and capital markets
CREAF	Ecological and Forestry Applications Research Centre – Barcelona, Spain
CNRA	California Natural Resources Agency
Grey water	Domestic wastewater excluding any foul water
Horticulture Industry	Sector responsible for production of fruit, vegetables and ornamental plants
Landscape Industry	Sector responsible for design of landscapes
MAR – Managed Aquifer Recharge	Intentional addition of water to groundwater aquifers for later reuse
PFAS – Per and Polyfluorinated Substances	Large and complex chemicals which do not degrade easily
TSE – Treated Sewage Effluent	Sewage water that has been treated to certain standard

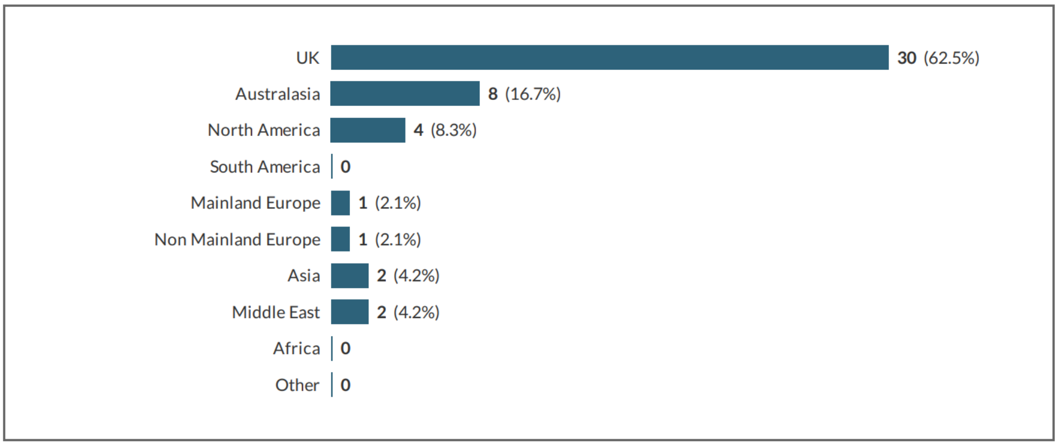
13. Appendix A – Nuffield practitioner survey

A public survey was conducted using Aberystwyth Jisc online survey software as part of the Aberystwyth Nuffield Masters Programme. A total of 49 responses were received with a wide range of disciplines represented.

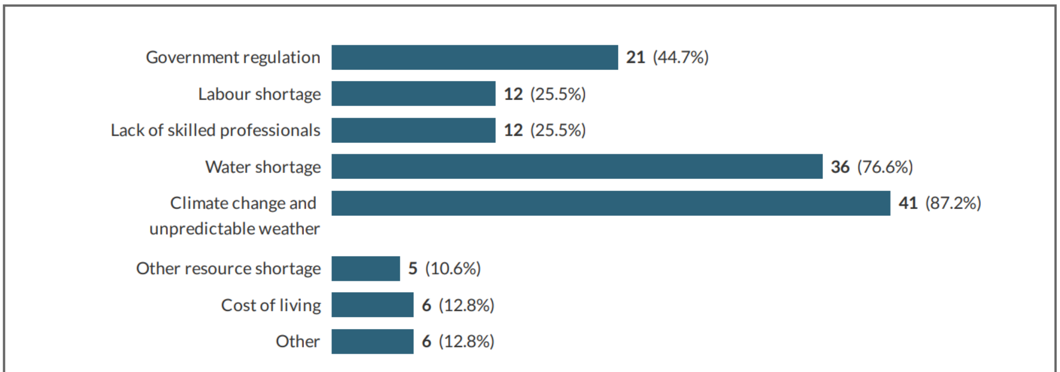
1 What sector do you work in?



2 What is your professional location?



3 Can you select, in your opinion, the three most important future threats to the agricultural, horticultural and amenity sector in your region?

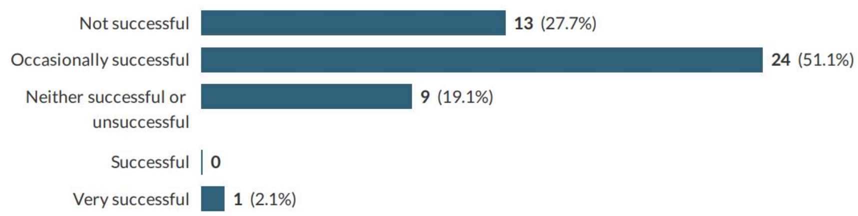


Multi answer: Percentage of respondents who selected each answer option (e.g. 100% would represent that all this question's respondents chose that option)

4 What does the term 'water security' mean to you?

Showing first 5 of 43 responses	
Ability to rely upon water availability	1082370-1082352-114514020
Having sufficient water resources throughout the year to successfully grow food, take care of our natural environment and live our lives.	1082370-1082352-114514290
Having enough water for people, businesses, agriculture and nature, now and in the future.	1082370-1082352-114514891
Having consistent access to safe drinking water.	1082370-1082352-114515262
making sure we protect water for future generations	1082370-1082352-114515509

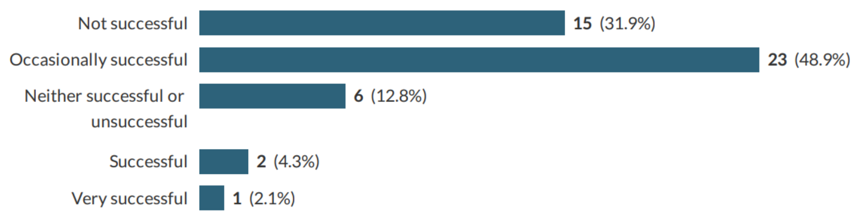
5 In your opinion, how successful do you feel current regulations and industry initiatives have been in addressing water security?



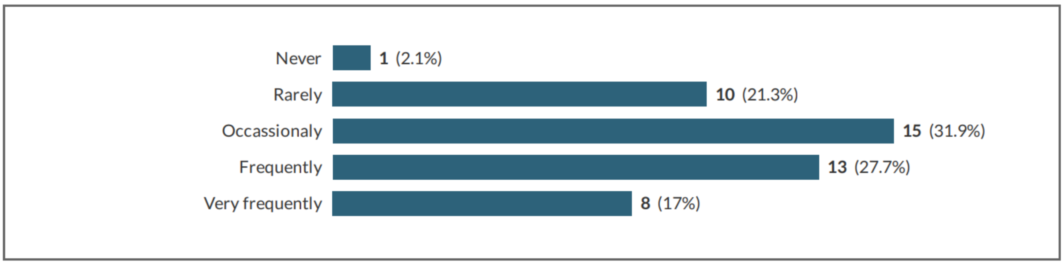
6 What does the phrase 'integrated water management' mean to you?

Showing first 5 of 42 responses	
Managing water in a holistic way by joining the dots between water resources, wastewater management and environmental benefits.	1082370-1082352-114514020
Design and construction of systems which consider all water considerations (supply, use and sensitive disposal) in a project, whether that be a housing development, a golf course, a farm etc.	1082370-1082352-114514290
Considering all aspects of hydrology and water management together, from a spatial and temporal perspective.	1082370-1082352-114514891
The ability to use water for more than one purpose, i.e. water re-use whether that be rainwater harvesting, grey water recycling and effective SUDS solutions.	1082370-1082352-114515262
trying to take a holistic view, but it seems harder than one might thing as people work in silos	1082370-1082352-114515509

7 In your opinion, how successful do you feel current regulations and industry initiatives have been with regards to integrated water management?



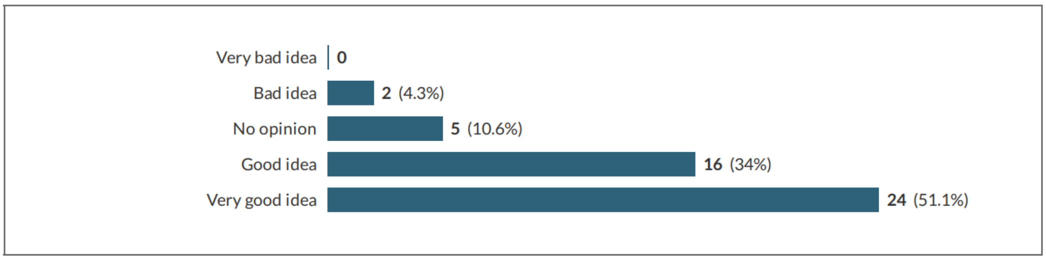
8 How often do you speak to professionals outside your immediate field on topics related to water security or integrated water management?



9 What difficulties have you experienced in your professional life when trying to facilitate integrated water management and improved water security?

Showing first 5 of 41 responses	
Where do I start. Regulation is archaic with regulators silo focussed also. Funding processes in water sector make it difficult to avoid cross subsidising. Programmes for water, flooding, environment, etc have different timeframes, making it hard to align.	1082370-1082352-114514020
Cost of installing rainwater harvesting, especially treatment and careful storage to mitigate health risks eg legionella. I still can't believe such measures aren't mandatory in housing developments though. Some positive government policy could be great here.	1082370-1082352-114514290
Lack or central co-ordination, lack of funding, difficulty of engaging large numbers of stakeholders.	1082370-1082352-114514891
Current legislation and regulations are prohibited in enabling large scale, housings development based solutions whether those be directly linked to water regulations which don't enable such a solution or linked into building regulations where builders aren't required to deliver such solutions.	1082370-1082352-114515262
each market sector and the people within are only concerned with their priorities, water should be all our priorities, once you are informed it changes your outlook and way of working, education is key.	1082370-1082352-114515509

10 Do you have an opinion on reusing wastewater? The definition of wastewater for this question is tertiary treated sewage (3 stage treatment process commonly used in developed countries' sewage treatment systems prior to watercourse discharge) and/or drainage water.



11 Can you select, in your opinion, the three most important water security and integrated water management measures for your geographical area?

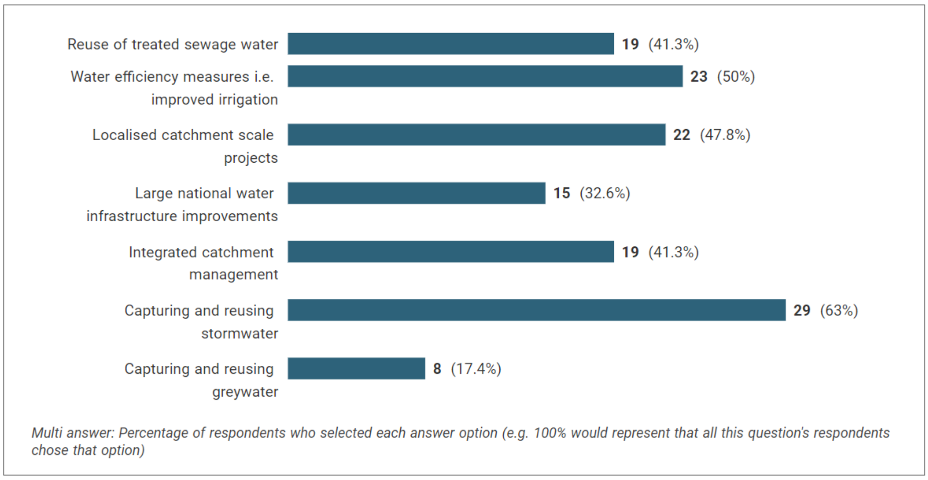


Figure A1: Results of online survey conducted with professionals involved with water management. A total of 49 responses were received from a wide range of disciplines. Dominant location of those surveyed was the UK with some respondents from Australasia, Europe and North America.

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