# COLLABORATIVE APPROACH TO GREEN ENGINEERING

**Dr Tim Johnson**
TREENET; University of South Australia – STEM; Flinders University; City of Mitcham

## Abstract

TREENET supports research and knowledge sharing to better integrate trees into cities. Since it began in 1997, TREENET has collaborated with industry, government, research and educational institutions to progress Australian urban forestry. The understanding that trees are fundamental assets which support healthy and resilient communities is now more widespread due to TREENET, to similarly focused agencies worldwide and to global awareness and concern regarding climate change and urbanisation. In response to this increasing awareness and concern, TREENET must continue to evolve to better help its members and others to serve their communities. Species trials and stormwater harvesting to nourish street trees were major foci during TREENET's early years and these remain high priorities. Collaboration and networking also remain high priorities, they are essential to achieving TREENET's vision *to enhance the role of trees in the urban forest and to engage the community in this endeavour*. Digital technology was relatively slow and expensive when TREENET began; even the most enthusiastic of supporters baulked at making online contributions via dial-up internet. High speed wireless internet has since given TREENET the opportunity to better engage its network and to increase collaboration across communities, industry, governments, researchers and volunteers. To support increased engagement, this paper examines some past and current collaborative research projects from the author's perspectives as a TREENET volunteer, researcher and local government arborist and engineer. This is not an academic paper; it presents some past and current research projects as case studies, describes how these collaborations evolved, considers common elements which contributed to their success so these might inform further progress, and it suggests some possibilities for future collaboration which might help to green cities into the future.

## Introduction

The 2020 National Street Tree Symposium was TREENET's 21st annual conference, the first under Lyndal Plant's leadership and the first conducted online. The global pandemic prevented the annual migration to Adelaide and the highly anticipated networking and meeting with friends and colleagues. Out of necessity came new beginnings and opportunities: TREENET's first National Street Tree Symposium with international reach, in real time. It is good to celebrate success and progress, but restriction and loss in 2020 has helped many to focus on what is most important now and what lies ahead. TREENET must focus and adapt to thrive and to remain relevant in the changing environment. TREENET must focus on what is important now and plan for what will become more important in our climate emergency, Black Lives Matter, record national debt, increasingly urbanised post-COVID-19 global pandemic future.

The breadth of topics covered in two decades of annual face-to-face symposia acknowledges the necessity for interrelated disciplines to work together to put trees into the service of communities. Past progress within and between disciplines is reflected in the chronology of symposia dating from 2000. The relationships between human health and wellbeing, urban trees, water management, and sustainable and resilient cities have become clearer through TREENET's Proceedings over these decades, as has the focus on urban heat island mitigation through green engineering. Recent papers clearly demonstrate how best practice urban forest management is an increasingly appropriate and urgent course of action in response to the climate emergency. They detail approaches to inform species selection, trial and establishment so that newly-planted trees will thrive in the changing climate. These papers remain freely available under the ***Education*** tab at www.treenet.org. Although TREENET is a small participant in the global initiatives reflected in these Proceedings, in Australia it is an important independent link between community, industry and government. TREENET has experience, support and networks; it is time to extend and apply these more widely.

## Recent history

On the 21st February 1995 the Royal Australian Institute of Parks and Recreation held a seminar titled *Trees in the Urban Environment* (RAIPR 1995). This seminar included presentations which covered disciplines including botany, arboriculture, civil engineering and asset management with respect to power and water utilities. The issues of the day were presented from the perspectives of the different agencies. The conference might have been promoted as a preliminary final in the contest of urban trees Vs the rest of the world.

Asset managers presented trees as imposing unnecessary cost burdens on business. Mechanisms of root damage to homes were explained (Goldfinch 1995). The local electricity agency suggested the way forward included '…*innovations in its distribution network*…' and '…*Local Government co-operation i.e. joint trenching*'(Parker 1995), which in hindsight appears to suggest they sought council help with developing innovative power supply solutions and/or financial contributions toward replacing Stobie poles – a previous innovation of the agency patented in 1925 – with technologies more appropriate to the approach of the third millennium. The breadth and depth of the issues were well summarised by the asset manager of South Australia's Engineering and Water Supply Department who advocated closer cooperation with local government, noting that '*The question then is how to get other organisations to accept more of the risks of nuisance and damage incurred by street trees and to share in an equitable manner more of the costs'* (Thompson 1995).

Despite the suggestion of future cooperation, the most observant of investigators would have found little evidence of common ground from which to work together to resolve the issues, but the need was clear. In his Opening Address the president of the Local Government Association of South Australia, Mr John Dyer OAM, stated '*We must enlist social and cultural awareness and legislative back-up*'. Two years later TREENET was founded. Social and cultural awareness of the benefits of trees is now high and continues to rise. The droughts, heatwaves, mental health crises, bushfires, floods and the pandemic of the last two decades have informed communities across this nation of the urgent need to integrate trees as essential service infrastructure in our third millennium cities.

## Collaborative green engineering research

### TREENET street tree species trials

TREENET's initial research work focused on increasing urban forest species diversity through tree trials. Trials established in several states are reported in papers from previous symposia. These and suggested practices for establishing new trials are available from the *Street Tree Species Trials* links under the ***Research*** tab at www.treenet.org. Many of the earliest trials were initiated by nursery industry champion and TREENET co-founder Mr David Lawry OAM.

### Wilga

The Wilga (*Geijera parviflora*) is listed in South Australian regulations (electricity and water) which permit its planting beneath certain powerlines and more than 2 m from sewer infrastructure. This native species of northwest Victoria, South Australia and inland areas of New South Wales and Queensland was unknown to the many South Australian nursery staff when contacted by the author during the 1990s. Across the Pacific, Gilman (1997) was familiar enough with it to report the species as being a hardy small tree with a life expectancy when grown in streets and car parks of 30 to 50 years. The author had read Gilman's text, seen Wilga listed in the regulations, inspected the few mature specimens that existed in the Waite Arboretum and in parks and gardens around Greater Adelaide, and had sought to plant the species over several years but had been unable to procure any. Totally independently and unknown to the author, nurseryman David Lawry had also been seeking Wilga stock and had managed to locate some. David made the road trip to Queensland to inspect the forestry tubestock which he purchased and brought back to South Australia in his Kombi to pot up and grow on.

David and the author met at the stand where the Wilga saplings were displayed, at the only local government expo that either has attended in their combined total of 92 career years to date. That meeting led in 1997 to what was possibly the first trial planting of Wilga as a street tree in South Australia.

Those initial plantings have matured into healthy, attractive street trees in the verges of the western end of Garfield Avenue in Plympton (Figure 1). Wilga is now a stock item for many commercial nurseries; it is resilient and climate hardy in most soils and in exposed sites. Wilga has proved to establish reliably and to thrive in streets in cities and towns in arid and semi-arid zones across Australia. Wilga provides a dense, shady canopy with few if any issues with leaf, flower or fruit litter. Early learnings included that fertilizer is highly beneficial and formative pruning is essential to manage clustered branch attachments and to establish an appropriate growth habit for street trees. Some published material suggesting the species grew slowly has proved inaccurate, with growth rates of half a metre per year or more achieved with adequate watering and fertilizer application, although competition with turf can substantially slow growth in early years.

**Figure 1.** Wilga (*Geijera parviflora*) street tree trial planted in 1997 in Garfield Avenue Plympton, South Australia; images show the same tree in 2011 (left) and 2018 (right).

## Chinese pistachio

Chinese pistachio (*Pistacia chinensis*) was another early trial species; it was inspired by a neat example which grew in a street in suburban Ashford (Figure 2). In 1999 the resident living nearby admitted to having planted the tree 32 years previously. With its bipinnate foliage, the shady canopy of this 6 m tall tree looked similar to a small Desert ash (*Fraxinus angustifolia*) and it appeared to be just as hardy. There were no noticeable impacts on the nearby footpath, kerb or road which all appeared to pre-date the tree. Nursery stock was sought but, as with the Wilga, Chinese pistachio was not locally available in quantity and quality was often poor. Showing a picture of the Ashford example at the 2000 TREENET Symposium led to discussions with commercial growers which soon resulted in increased availability. Early trial stock was small, typically leggy and its quality was highly variable but within a few years good stock became readily available. Several larger and older examples were later located in Angaston, South Australia; these also indicated the species' resilience as a street tree (Figure 3). Chinese pistachio is now a stock item for many nurseries and it can be seen thriving in towns across semi-arid Australia. An inspection of the Ashford example in 2020 revealed it was in good health and remained structurally sound; a small rise in the kerb adjacent to the tree was noted and about 4 m of the concrete footpath appeared to have been replaced a few years earlier.

## Ivory curl

Ivory curl (*Buckinghamia celsissima*) seemed an unlikely candidate for a street tree species trial in South Australia, yet David Lawry liked the species' appearance and knew it grew in Sydney and Melbourne so brought some to try in Adelaide's hot, dry clay. This northern Queensland species of the Proteaceae family was expected to handle Adelaide's heat but its performance in low humidity and poorly draining soil was unknown. Initial plantings revealed winter weather was a concern; trees exposed to cold westerly winds grew better on the eastern side of the canopy with growth stunted toward the west. Fortunately this problem was observed in juvenile trees only, and after two decades they have grown full and balanced canopies. Many of the trial trees flower profusely and are utilized by insects and nectar-feeding birds. Trees planted in 1998 (Figure 4) have matured into attractive small trees. The performance of these initial Ivory curl trials justifies further investigation this species across semi-arid regions, but noting its reported susceptibility to frost.

**Figure 2.** Chinese pistachio (*Pistacia chinensis*) street tree in Herbert Road, Ashford, South Australia; images taken in 1999 (left) and 2020 (right).


**Figure 3.** The dense canopies of mature Chinese pistachio (*Pistacia chinensis*) street trees following the breaking of the Millennium Drought indicate the species resilience (Images: Angaston, South Australia, December 2011)

**Figure 4.** Ivory curl (Buckinghamia celsissima) street tree trial in Kurralta Park, South Australia; images taken in 2000 (left), 2015 (centre) and 2018 (right).

## Tree species trials: some data is better than no data

The information provided above is sufficient to justify further planting of Wilga, Chinese pistachio and Ivory curl under conditions similar to, or likely to become similar to, those currently experienced in suburban Adelaide.

Familiarity with these three species across much of Australia is, in part, due to TREENET having previously provided information such as contained in this paper. Now consider how limited this information actually is.

The most valuable information provided above is visual: it is images. No numeric data has been provided here other than the year the photographs were taken, yet in the past such images have been highly effective in encouraging practitioners unfamiliar with these species to plant them, on a trial basis at least. Images are highly valuable visual data.

Unlike TREENET's early days when scanners and floppy discs produced pixelated mosaics, high-definition digital images are now quick and cheap to collect, store and retrieve. Smart phones automatically record location and date when photographs are taken, making manual recording redundant. Images include familiar objects which impart scale (e.g. people, footpaths, cars and Stobie poles which, incidentally, '*are a good reminder of man's ability to generate electricity*' (Kerrigan 1997)), so data collection doesn't always need to include measurement. A good image is possibly the most time-effective and cost-effective means of simultaneous data collection and storage available, it can be captured with minimal planning, preparation and equipment, and it has been demonstrated that it provides substantial return on minimal time invested.

A series of images can tell a life story. Photographs of trees when planted then periodically during their growth and maturity can record the rate of growth, seasonal characteristics, infrastructure impacts and any other related occurrence. Rigorously monitored, replicated trials and statistical analyses will produce more data with value specific to the particular experiment being conducted, but it only takes one tree to grow well to maturity to prove that that species can thrive in that location. Photographically recording the fact that a species can thrive in a particular location should be a high priority.

Academically rigorous empirical research and statistical analysis are essential to progress green engineering and many of TREENET's collaborators are heavily involved in this. Few in the community can be expected to commit to academic research but many are keenly interested in trees, urban forestry, the problems of climate change, and most are able to take a photograph. A user-friendly method to upload quality images to a central database is needed. Data captured (image, location and date) should be readily searchable spatially and by tree species. Available spatial data including climate and soil characteristics might also be cross-referenced and searchable.

Such a system would enable arborists, citizen scientists and others to quickly capture and share photographs of successful street tree establishment in our cities and towns. TREENET is currently planning to develop such a system. This has been a goal since TREENET began, but early digital technology and late analogue humanity didn't align to achieve it in the first two decades. It is likely that a method to contribute to this database and to utilize the data will be demonstrated at the 22nd National Street Tree Symposium in 2021. In the meantime, TREENETers could begin to take photographs of street trees which impress them for any reason, for uploading when the system becomes available. Several images would ideally be taken to show the whole of the tree in its local situation as well as detail of leaves, flowers, fruits, bark and any other items of interest.

## The future of tree species trials: improved collaboration and coordination.

Collaboration has been fundamental to all of TREENET's species trials; trials would not have happened without the support of local government, local communities, academe and the nursery industry. Trials were usually planted by local government on land under the care of local government. Trial methods were developed by practitioners, students and academics.

Unfamiliar species meant exposure to heightened risk; risk the species would fail to thrive, risk of potential litter, allergens and other hazards, risk of weediness and of potential infrastructure impacts. The nursery industry bore increased risk propagating and growing unfamiliar species, often for several years prior to the potential to realize any return at point of sale. The community bore the risk of possibly waiting years for trees to establish in their streets should the trials fail and require replanting with an alternative species. Without risk there can be no innovation, no progress. Without the extra work which inevitably results from developing and progressing anything innovative (extra communications, procurement issues, monitoring of trials on top of full task lists) there would be no trials. Without commitment to ongoing collaboration, to risk and to extra work, there can be no tree species trials, no innovation and no progress.

Nursery and local government participants in TREENET's early species trials are now well into the second half or final quarter of their career. Despite their unwavering interest and commitment, some won't see the next generation of trees mature. The boomers must relinquish responsibility for the next generation of tree trials and support the millennials and Gen Zs who will guide, establish and learn from these next trials and apply their new knowledge through to the middle of this century and beyond. *The urgency of now* (Lambe 2020), requires that TREENET increases its contribution to urban forestry nationally by:

- developing a means to easily and quickly collect and share data and imagery of existing street trees
- establishing a national network of millennial and Gen Z practitioners to champion the next generation of tree species trials
- engaging nursery industry champions to work with TREENET to produce trees for trials

Persons wishing to be part of this next generation of street tree trials should contact TREENET. Early-career industry and local government practitioners are particularly encouraged to express their interest. There is no closing date for expressions of interest.

## Stormwater harvesting for street tree irrigation

The expansion of roof and sealed pavement areas due to urbanisation increases storm water runoff which reduces soil moisture needed to support urban trees and other plants. Additional impacts of surface sealing include creation of heat islands; increased flooding severity and frequency; diminished water quality and base flow in riparian habitats; local extinctions of aquatic species and degraded marine environments. To help to reduce these impacts and restore the liveability and environmental qualities of urban areas TREENET has collaborated to conduct stormwater harvesting research with partners including the City of Mitcham, the Government of South Australia, the Adelaide and Mt Lofty Ranges Natural Resources Management Board and, more recently, with the Board of the local Landscapes SA region: Green Adelaide. For nearly two decades the City of Mitcham has, with financial and in-kind support from these and other collaborators, facilitated green engineering research by building experimental equipment into novel green infrastructure.

### Development of the TREENET Inlet

Collaborative research with Mitcham Council began in response to a request from TREENET in September 2001. Council approved the use of Claremont Avenue, along the southern boundary of the University of Adelaide's Waite Arboretum, as a site for ongoing green engineering trials. Initial research at the site engaged the support of staff and students of the University of South Australia to investigate various kerbside inlet designs (Porch, Zanker & Pezzaniti 2003). Further inlet design tests built upon the results of this initial study over more than a decade, leading to the development of the TREENET Inlet.

Some practitioners who heard about the early TREENET Inlet research were quick to condemn the concept. Opinions like 'they'll just clog up with sediment' and 'you can't put water into reactive soil' were common; they were also unsupported by data or literature. The apparent innate negativity toward small-scale stormwater harvesting was not surprising, as innovation needs to be driven by one whose vision is beyond the status quo and not discouraged by unsupportive results during what is typically a lengthy development process. Naysayer deafness and a 'never give up' personality type seem to be prerequisites for innovation. The TREENET Inlet exists because its inventor didn't listen and didn't give up.

With the naysayers still saying nay, when the inlet was marketed some of TREENET's friends and supporters saw its potential and began to ask 'How much water do Inlets harvest?' 'How much impact do they have on water availability to street trees?' 'How and how much do they impact ground movement?' There were many questions and these couldn't be answered with a photograph; they needed experiments to provide empirical data.

In 2014 the City of Mitcham's scheduled kerbing renewal project in Eynesbury Avenue in Kingswood provided an opportunity to install TREENET Inlets. This working demonstration supported investigation of the Inlet's benefits, costs and impacts on water quality. The Adelaide and Mt Lofty Ranges Natural Resources Management Board and the SA Environment Protection Authority supported the study with grant funding. The University of South Australia's Professor Simon Beecham and Dr Baden Myers saw the Inlet's potential and they committed to supervising a post-graduate student's research at the site. The Government of Australia's Research Training Program contributed funding for tuition fees and a student scholarship. Mitcham Council built the infrastructure and supported the study. Dr Harsha Sapdhare's findings showed the choice of backfill material influenced the removal of heavy metals (Sapdhare et al. 2018). The inlet was shown to be an effective stormwater harvesting device for use in kerbs on low gradients (Sapdhare et al. 2019).

## TREENET Inlets and ground movement in moderately reactive clay

Another study conducted concurrently at the Eynesbury Avenue site involved regularly surveying kerb elevations at the TREENET Inlets, at regular offsets from the inlets, and midway between the inlets. Survey points were also installed in the adjacent road surface and elevations were surveyed to coincide with the kerb surveys. Analysis of these data showed no difference in ground movement between the locations of the inlets and points midway between the inlets. That is: TREENET Inlets coupled to leaky wells did not affect ground movement in moderately reactive soil. This experiment's data, analyses and findings will be drafted for publication in the near future. Furthermore, the inlets did not clog with sediment and they continue to function without maintenance other than routine mechanised street sweeping.

## TREENET Inlet hydrological benefits at catchment scale

Mitcham Council's General Manager of Engineering and Horticulture, Mr Howard Lacy, suggested in 2015 that a study was needed to gauge the catchment-scale effects of the TREENET Inlet. An suitable sub-catchment for such a study was identified in the established suburb of Hawthorn. Grant applications were lodged, funds were received and flow measurement and water quality sampling equipment were installed at the outflow from the catchment. Baseline data were collected for a year before more grant applications were lodged, more funds were received, previous grants were acquitted, TREENET Inlets were installed and monitoring was continued (Figure 5). Annual grant applications, reports, acquittals, planning sessions and experiments continue; much data has been collected and much has been learned.

The catchment's characteristics were modelled in great detail as part of Hussain Shahzad's research toward the degree of Masters in Engineering in Water Resource Management. Following completion of his Masters degree Hussain commenced further research toward his PhD, through which he has calibrated stormwater modelling software against the catchment's measured flow characteristics prior to installation of the TREENET Inlets. Hussain's model enables measured outflows since installation of the inlets to be compared with the outflows that would have been observed had the inlets not been installed, thus allowing the impact of the TREENET Inlet at the catchment scale to be quantified. Results to date have shown that TREENET Inlets operating under field conditions (i.e. subject to urban leaf litter and sediment loads) harvested an average of 4.5 kilolitres each in 2017 and 1.8 kilolitres each in 2018 (Shahzad 2020). The difference in harvest quantity over these two years is likely due to rainfall variability. These inlets continue to provide maintenance-free service. This research is ongoing; papers presenting these initial findings will shortly be submitted for peer review and publication.


**Figure 5.** Over 180 TREENET Inlets built into the kerb (left) direct stormwater into leaky wells in the street verge (centre), to provide passive irrigation to street trees and reduce and delay flows reaching the monitoring equipment at the catchment outflow (right).

## TREENET Inlet tree benefits

In the gauged Hawthorn sub-catchment where hydrological studies summarised previously are underway, the benefits of the harvested stormwater to street tree growth and urban cooling are being investigated (Figure 6). PhD Candidate Xanthia Gleeson's research has shown that mature White cedar (*Melia azedarach*) trees with TREENET Inlets in their root zones transpired 29% more water during summer than similar trees without inlets (Gleeson 2020). Additionally, photosynthesis was 94% higher, trunk diameter increased 25% more and height increased 50% more for White cedar saplings with inlets than for saplings without inlets (Gleeson 2020). This research is ongoing; papers presenting these initial findings will shortly be submitted for peer review and publication.

**Figure 6.** Flinders University researchers and PhD students installed sap flow meters in street trees to measure water use by trees with and without TREENET Inlets. Data from sensors in radiation shields (right) allow comparison of temperature and humidity in tree canopies and other street locations to quantify the cooling benefit of the additional water provided by the inlets.

## Progressive research, building on earlier experiments

Collaboration has helped research partners to focus multi-disciplinary knowledge and resources on delivering improved, practical solutions for communities as well as further educating professionals in green engineering-related roles. An example of this alignment between research and practical application is a relatively new project which is investigating ground movement in highly reactive soil. It is well known that water extraction by trees can increase ground movement (settlement) in reactive soil. It has also been shown that moderately reactive soil underwent less movement near trees when rain was infiltrated through permeable paving adjacent to trees (Johnson et al. 2020). To build on this knowledge, an experiment has begun to investigate whether water infiltration (e.g. from stormwater harvesting) and water extraction by trees might interact to reduce ground movement in highly and extremely reactive soil in the City of Mitcham. Preliminary geotechnical investigations and monitoring have begun at St Marys Reserve in the suburb of St Marys, about 8 km south of the Adelaide CBD (Figure 7). Soil water content (suction) has been measured in winter and summer, a grid of survey points has been established to measure movement in surface elevation and regular elevation surveys are ongoing.

**Figure 7.** University of South Australia – STEM academics volunteer their expertise to benchmark the water status of extremely reactive soil at St Marys Reserve.

Percolation tests to measure infiltration rates in the reserve's soil are planned, along with installation of neutron moisture meter access bores and commencement of regular soil moisture monitoring. Plant water status at the site will be measured for several eucalypt species of various ages. Soil moisture measurements and ground movement surveys will be continued (subject to ongoing funding) until representative seasonal variation has been recorded, which is likely to be at least the next two years given the current *El Nina*. When these representative benchmark data have been acquired, a soakage trench will be built and soil moisture and ground movement will continue to be monitored following infiltration of measured volumes (many kilolitres) of water. It is anticipated that ongoing measurement will reveal ground movement impacts of stormwater infiltration on the highly and extremely reactive soil and impacts on plant water status.

Mitcham Council's increasing reputation for applied research led to an opportunity to work with the University of Melbourne to investigate the performance of pervious asphalt made with crumbed rubber from recycled tyres. The full scale paving trial at St Mary's Park (Figure 8) is co-funded by Council, the University of Melbourne, Tyre Stewardship Australia, the Adelaide and Mt Lofty Ranges NRM Board and other industry partners including Merlin Site Services, Global Synthetics and Pacific Urethane.

Using recycled rubber material has the potential to greatly reduce landfill and related pollution. By reducing stormwater runoff pervious pavements help to address erosion and pollution of waterways, and by retaining stormwater in the soil where the rain falls it becomes available to trees to help to mitigate urban heat islands. In addition to harvesting stormwater, the use of lighter-coloured stone in the pavement material reduces the amount of heat it absorbs. Being in an active car park, the experimental pavements are used daily by cars and trucks. The pavements are fitted with gauges to measure strain at different depths below the surface. A geothermal heat exchanger is also installed beneath the asphalt to provide sustainable, self-contained heating for the sports clubrooms at the site.

The Adelaide and Mt Lofty Ranges NRM Board's *Sustainable Water Management Grant* which Council won in 2019/20 enabled this research to be extended by installing a high-precision weather station at the site to provide accurate temperature, solar radiation, rainfall intensity and other data to inform analyses of pavement performance. The weather station also provides data for the ground movement study in extremely reactive clay soil described previously, as the two sites are 800 m apart.

**Figure 8.** Collaboration between the City of Mitcham, University of Melbourne and industry partners has enabled structural and environmental performance of pervious asphalt which incorporates tyre-derived aggregates to be investigated in a full scale working demonstration at St Marys Park.

## Collaboration = research = knowledge = solutions

Local government is really good at building and maintaining public infrastructure with pubic funds but isn't famous yet for engaging in novel, field-based, applied research. Local government is good at managing infrastructure because it applies practices that have been developed and refined over decades to efficiently and cost-effectively deliver to accepted standards and specifications. Standards and specifications are essential to support the open tendering and market forces which ensure that public funds are appropriately utilised. Standards and standardisation drive efficiency of public infrastructure delivery.

Improving upon accepted standards requires deviation from standardisation. Specialists and organisational structures tasked with optimising efficiency and effectiveness through standardisation may, at times, struggle to deviate from standards. Innovation requires a different skill set, multidisciplinary expertise and creativity, in addition to naysayer deafness and never giving up.

Deviating from standards increases workloads and it presents risks. Not that business as usual is risk-free, indeed many of our current urbanisation and environmental challenges have resulted from the application of accepted standards and practices over long time periods, but unfamiliar risks are often perceived as being potentially worse than familiar risks which are more likely to be underrated (or inadequately considered). Working with experts helps to foresee and avoid or minimise and manage risks.

Risk management was a major consideration when the experiments described in this paper were designed. Experiments were designed and locations were selected to avoid or minimise risk. Students, university technical staff, academics and industry champions all work to manage risk and to meet the inevitable increase in workloads associated with innovation. Universities provide substantial in-kind support, with many students and academics (staff and honorary) making very substantial voluntary contributions of their time and expertise.

Grants made by the Government of South Australia helped to keep TREENET afloat in its early years. More recently, the government and its agencies have provided funding and in-kind support to Mitcham Council toward green engineering research. The Adelaide and Mt Lofty Ranges NRM Board was a regular contributor and it is hoped that its successor, the Green Adelaide Board, might continue to build on this work. Government of Australia contributions to PhD student scholarships and fees are also substantial. Without these financial contributions the research described in this paper would not have been possible.

Equipment needed to investigate the performance of novel green engineering, and sometimes the green infrastructure itself, can be beyond council budgets which are usually stretched when renewing assets under like-for-like, business-as-usual approaches. Mitcham Council has for many years allocated a recurrent operating budget to support green engineering research. Industry has also contributed financially and in-kind to support research. Council and industry contributions enable grant applications, as grants typically require matching funding by project proponents.

## Observations toward future progress

TREENET's former director David Lawry had the idea for small stormwater harvesting devices to be located in the root zones of individual street trees. Designing the prototypes, understanding how they functioned and monitoring their performance needed private sector and university inputs. Building working prototypes in a public street needed local government support. Substantial investment was made in students, infrastructure and equipment and there has been massive in-kind support. Collaboration between local and state government, industry and universities has been essential to progressing all of the research projects described in this paper. Interdisciplinary, interagency and community collaboration are essential to progressing greener engineering.

## Project funding

Although their goals often overlap, governments, academe and industry have many and varied project planning, delivery and reporting processes and timescales. These different processes can complicate project initiation and coordination. Local and state budgets and grant programs are often restricted to a single financial year, but universities run their student programs by calendar year, so guaranteed financial support for research over a single calendar year can be difficult to obtain. Honours projects need to be able to start early in the university's calendar year, but local and state government planning and funding cycles may not support this.

Annual grant cycles might receive applications until September and make funds available by November or December. Research project planning might then begin immediately following notification of grant success – through the Christmas/New Year holiday period. A prospective student would not have received their assessment, not know of their eligibility to pursue higher education, and not have had any opportunity for input into a grant application in that timeframe. Masters and PhD students may be subject to similar grant cycles within their longer-term research projects, with an unsuccessful application during any year having potential to end the collection of data on which their study relies. This presents considerable risk to students, in addition to other risks described previously.

Although still subject to annual funding cycles, the City of Mitcham's operating budget for WSUD research has been embedded into long term financial planning. This budget has allowed cash flow to be managed between grant funding cycles. Annual expenditure on ongoing projects, such as stormwater quantity and quality monitoring in the Hawthorn catchment and regular ground-movement surveys at St Mary's Reserve, has been kept within the recurrent budget so that these projects can continue if applications for industry or grant support are not successful. This provides current students with certainty regarding data collection, to at least the end of the financial year. Expenditure on these ongoing tasks begins in the 1st quarter of the financial year, which is when annual grant program applications are typically lodged. Successful funding applications allow additional research components to be added following receipt of funds, which is often late in the 2nd quarter. In this way research projects might be expanded over successive years, with a degree of certainty regarding ongoing data collection, provided recurrent costs are kept below Council's operating budget and that this budget continues to recur.

The importance of Mitcham's recurrent operating budget in terms of managing cash flow to enable ongoing data collection and project extension through grants cannot be overstated. Timing of annual grant processes could not guarantee ongoing monitoring to provide the data needed to inform most of the experiments described in this paper. Any council seeking to engage with academic institutions, state government, industry and others to search for practical solutions to current issues should consider allocating a recurrent operating budget for research. By matching Council's budget with industry contributions, then matching the combined Council and industry totals with grant funding, the City of Mitcham's WSUD research budget has in recent years been increased by four times. The history of past grant success and the opportunity to geometrically increase allocated budget in this way provides a real incentive to maintain the budget allocation to support and progressively build upon the research summarised in this paper.

The research projects described in this paper have over the past two years had a total annual expenditure of over $200,000 (funded by Council, industry, universities and grants; excluding in-kind contributions). As a national benchmark, gross domestic spending on research and development in OECD nations has been approximately 2.3 – 2.4% of GDP since 2012 (OECD 2020).

Being primarily focussed on service delivery to meet existing standards, local government's expenditure on research and development is likely to be below this national benchmark. However, the opportunity to attract matching funding through industry contributions and grants, and opportunities to collaborate to address some of local government's more urgent social and environmental issues, might suggest a review of the sector's approach to practical, applied research is timely.

## An opportunistic and piecewise approach

Investigating the stormwater management capacity of TREENET Inlets deployed at the catchment scale was the specific intent of the experiment for which inlets were installed across the catchment at Hawthorn. This project provided the opportunity for further study, to assess tree water use and function in the inlet-equipped catchment and to compare this with trees growing without inlets. This and other possibilities were considered at the time the original project was being planned. Using the existing inlet installations enabled the tree water use experiment to begin with little additional equipment, and the author's knowledge of related research by local Associate Professor Huade Guan suggested the opportunity for collaboration. Several years elapsed, however, before a suitably qualified and interested post-graduate student became available to pursue this additional research.

Xanthia's Honours study being very well received led to her opportunity to pursue further research, and this has allowed the project to be extended to investigate tree water use in relation to the eucalypts surrounding the highly reactive ground movement research site at St Marys. Thus the piecewise addition of further components to projects is opportunistically building knowledge based on prior investment and learning. Progressing research in this piecewise manner allows the extension of current work with minimal risk to ongoing projects. Designing projects to progressively build upon previous research may also improve the likelihood of future grant success.

Knowledge of the interests and priorities (current and future) of potential collaborators is essential to aligning future research to address mutual needs. Knowing what opportunities are available to potential collaborators, and being in the right place at the right time to harness opportunities, requires familiarity which can be best developed through ongoing relationships. Opportunities for some projects may not arise for years or longer, and if they are not seized when available they may easily be lost.

## Research opportunities through association

Much of the City of Mitcham's collaborative research grew from relationships established with academe through involvement with TREENET or when Council staff undertook postgraduate studies. Encouraging and supporting staff to pursue post-graduate research qualifications is an effective way to initiate relationships with potential collaborators. Professionals might, after a few years of experience, see possibilities for improvement in the workplace and so might be encouraged to pursue postgraduate studies to investigate these. Alternatively, a graduate who identifies a research need and opportunity to investigate it could raise this with an academic who may be able to suggest a suitable student to progress it. Academics routinely identify potential postgraduate students during undergraduate studies, but transitioning into further study can sometimes take years and keeping track of opportunities and potential students requires some attention.

Informal networking within industry, between disciplines, and between industry and academe may generate ideas and opportunities for innovation and collaborative research. Informal networking and creating time and opportunity for diverse groups and individuals with similar goals to discuss ideas freely, particularly over the long term, can help to identify opportunities for improvements and thus establish research needs and directions. Needs and directions may inspire long term goals which can be achieved piecewise through small actions. Graduates keeping in touch with former classmates through the early stages of their careers can be of great benefit to organisations and should be encouraged and supported, as should membership of professional associations. Local academics and scientists engaging with past students and other practitioners, through professional associations, can only help to inspire and facilitate ongoing, practical, applied research.

## Conclusion

Cities can be healthy, green, biodiverse places for communities to thrive. Green cities start with a choice, a political decision, but building them requires transdisciplinary regard and collaboration toward a shared vision. Green engineering can deliver a city's natural and built components side by side, designed not just to avoid conflict but to coexist so each enhances the performance of the other.

Trees and other vegetation are fundamental to green, healthy cities, so built elements must accommodate the biological needs of plants and all the natural components as well as meeting accommodation, transport and other essential civil service requirements. Servicing the biological needs of a green city's natural elements through design will help societies progress toward environmental and financial sustainability. By collaborating with other professionals, by sharing knowledge between disciplines, we can contribute to integrating the natural and built elements of our cities by design.

The transition to green cities will be as significant as the transitions from analogue to digital technologies and from fossil fuels to renewable energy. As with these other major transitions, building green cities will be generational achievement; it will occur as current infrastructure reaches the end of its service life and requires renewal. We all have the opportunity to be part of this major global transition now and over the coming decades.

More than half of the world's population live in cities. As horticulturists, engineers, urban foresters, designers, planners, arborists, we can all contribute to making cities healthier places for most of the people on the planet. Since TREENET began it has promoted networking and knowledge sharing, and experience has shown members have great need to access knowledge for application in their communities. Many champions have arisen to seek and share knowledge, but in the changing environment the need remains far greater than the supply. TREENET's relevance into the future depends on finding increasingly effective and efficient ways to obtain, store and disseminate green engineering-related information. Engaging the community in this endeavour, to obtain, store and disseminate green engineering-related information as and when they are able, is the challenge of TREENET's third decade. What and when are you able to contribute? Think about it, then speak with TREENET about it. Get involved.


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