WATER SENSITIVE DESIGN PERFORMANCE OVER THE PAST 10 YEARS: A ROAD MAP TO THE FUTURE.

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ABSTRACT

Over the past ten years, the percentage of people living in urban areas in New Zealand has increased from ~72% in 2008 to ~86% in 2018. Auckland's population has increased by over 200,000. Our existing infrastructure cannot keep up with the current rate of intense urbanisation, a situation which will worsen with increased rainfall from climate change. New solutions for stormwater management must be resilient so urban centres can adapt and remain sustainable. Providing good stormwater management solutions for the future requires an understanding of the effectiveness of today's existing systems.

The intensified land development across New Zealand has required new developments to manage at least a portion of new stormwater runoff on site so as to protect both stormwater infrastructure and natural waterways. Much of the increased stormwater runoff resulting from new developments has been managed through low impact or water sensitive design (WSD). Practitioners have designed raingardens, detention tanks, wetlands, permeable paving, swales and a myriad of other solutions to accomplish stormwater management over the past 10 years.

TO understand how WSD assets have performed over time 40 WSD assets installed within the last decade were revisited. The results of field inspections are presented herein. The current effectiveness of the WSD assets and reasons for failure are explored. Banded wetlands, raingardens, four types of permeable paving, stormwater detention tanks and vegetated swales were examined for condition and functionality.

Five raingardens which were installed as part of a residential subdivision that now lies within a mixed housing urban zone were revisited. It was found that after a decade, none remain. In a nearby residential area a more recent raingarden is operating near the design specifications but the property owner is finding it ugly and difficult to maintain.

In a residential development just inside the Residential Urban Zone, a comprehensive WSD increased property values and contributed to the subdivision becoming a sought after community. After 5 years most of the assets are intact and well maintained. However 3 km away, the banded wetlands, installed as a shared WSD asset within an industrial development, are in such poor condition that rehabilitation will be nearly as costly as the initial installation.

On the surface, maintenance appears to be the key to why some WSD succeed and others fail. A deeper look at the findings also indicates a more systemic failure than maintenance. The long-term success of a WSD depends on a number of factors including: regulatory framework, public awareness, engagement and maintainability. All parties involved throughout the lifetime of a WSD – the regulatory body the contactors who install the assets, the designers, the property developers and end users - all play a role in the successful implementation of WSD.

KEYWORDS

WATER SENSITIVE DESIGN, RESILIENCE, SUSTAINABLE

PRESENTER PROFILE

Linda joined ACH Consulting Ltd after immigrating to New Zealand in 2006. She trained in the US as an oceanographer and environmental engineer. Having achieved degrees in Chemistry and geology as well as an advanced degree in oceanography and marine geophysics, she has worked for NASA, Woods Hole Oceanographic Institution, US Geological Survey and others. A Scientist and an Engineer, she brings her multidisciplinary experience to engineering design.

1 INTRODUCTION

WSD is an engineering design philosophy which takes into account stormwater runoff, the drainage system, the receiving environment and attempts to minimise the effects of increasing urbanization. WSD practices include assets such as swales, constructed wetlands, raingardens, rainwater detention/reuse tanks and permeable pavers as well as proprietary devices.

It has been 27 years since *Technical Publication #10 Stormwater Treatment Devices Design Guideline Manual* (TP10) was introduced. During that time it has become standard practice to provide water quality treatment as well as volume and peak flow mitigation as part of development. The actual practice resulting from TP10 of providing WSD assets has helped to improve our awareness of the environmental outcomes of development and has had an overall positive impact. There are however ways in which WSD practices can be improved.

The rapid continued urbanization of Auckland and other New Zealand cities requires stormwater management to be integrated into the continued development process as existing infrastructure cannot be upgraded at a sufficient rate to keep pace with urbanization. The infrastructure in Auckland includes the stormwater network, combined sewer systems and water courses which double as part of that stormwater network. Over the past decade the territorial authorities' requirement for WSD practices has become ubiquitous. In principal the WSD assets have reduced the burden on the infrastructure and receiving environment. In practice the desired outcomes have only partially been achieved. An assessment of long term effectiveness and performance of the WSD assets already in place provides a way to refine both the design and implementation of these assets.

The following paper explores the results of the inspection of 40 WSD assets which have been installed over the past decade. Assets were assessed as to performance, appearance and design. Each asset was visually inspected and discussed with owners where available. Accessible design details were reviewed and in some instances consent notices on titles were obtained. By improving the knowledge of past performance of WSD assets and examining causes of underlying failures it is possible to improve the future outcomes of WSD approaches.

2 INVESTIGATION AND RESULTS

Of the 40 assets examined 2 were in excellent condition, 8 were in good condition, 5 were in fair-good condition and 7 were in poor condition. There were 13 underground tanks that had not been maintained since their installation in 2008 and are believed to be

in poor condition though access to the tanks was not possible. Additionally, 5 assets were completely missing. Table 1 shows the results of the field investigation of each asset.

Table 1: Results of field investigation

Asset	Condition	Comments	Type of Development
Wetland 1 Banded	Poor	Orifice partially blocked Full of pest species Forebay filled with sediment	Commercial –Lt Industrial
Wetland 2 Banded	Poor	Extra inlet bypassing the wetland Full of pest species (some natives remain) Forebay filled with sediment	Commercial –Lt Industrial
Wetland 3	Good	Some Plastic present in wetland could use gross pollutant traps upstream	Large Residential Subdivision
Wetland 4	Good	A few pest species present	Large Residential Subdivision
Wetland 5	Good	Oxygen weed is prolific. Red Sheen on water. Construction debris	Large Residential Subdivision
Vegetative Swale 1	Poor-Absent	Weedy, only the cesspit remains	Commercial –Lt Industrial
Vegetative Swale 2	Good	Some of the Scruffy domes have been grouted in place and damaged. Sumps need maintenance	Large Residential Subdivision Two different Developers
Vegetative Swale 3	Excellent	Client is pleased with the asset and appreciates the wild bush area it adds to his small urban property	Residential Single House Site
Vegetative Swale 4	Good	Is functioning well. Owner was unaware that there is latitude for planted species and is finding the Oioi hard to maintain	Large Residential Subdivision
Raingarden 1	Absent	While it was a condition of the RC the requirement never made it on to the Title Consent Notice	5 lot Residential Subdivision
Raingarden 2	Absent	While it was a condition of the RC the requirement never made it on to the Title Consent Notice	5 lot Residential Subdivision
Raingarden 3	Absent	While it was a condition of the RC the requirement never made it on to the Title Consent Notice	5 lot Residential Subdivision
Raingarden 4	Absent	While it was a condition of the RC the requirement never made it on to the Title Consent Notice	5 lot Residential Subdivision
Raingarden 5	Absent	While it was a condition of the RC the requirement never made it on to the Title Consent Notice	5 lot Residential Subdivision
Raingarden 6	Good-Fair	Property owner has no understanding of why it is there or what it is. Was unaware that it was required at consent stage	3 Lot Subdivision
Raingarden 7	Good-Fair	Full of silt from road works. Contractor doing the works failed to place silt controls in to protect the raingarden	Commercial –Lt Industrial
Raingarden 8	Excellent	Sump is clear and there appears to be no short circuiting or die off.	Commercial –Lt Industrial
Raingarden 9	Good-Fair	Some die off and rubbish present	Large Residential Subdivision
Paving 1	Good	Some die off due to summer heat	Commercial –Lt Industrial
Paving 2	Poor	Have used pea gravel instead of planting in the voids. A Few Gobi blocks have come loose and jack mat has come away from corners	Commercial –Lt Industrial

Asset	Condition	Comments	Type of Development
Paving 3	Poor	Clogged due to lack of maintenance needs a clean	Commercial –Lt Industrial
Tank 1	Fair	Outlet not connected to spreader bar. Tank itself is working.	3 Lot Subdivision
Tank 2	Poor	Orifice is blocked Tank in overflow	Infill housing
Tank 3	Good	Tank is empty orifice not blocked	Infill housing
Tank 4 Reuse	Good	Resident stated tank was filling with mains water due to lack of Maintenance. Landlord was taken to court tank working properly now	Large Residential Subdivision Each lot was sold to different builders
Tank 5 Reuse	Fair	Reuse component of Tank not being used. No automatic mains float switch was installed. Tank now is in overflow only	Infill housing
Tank 6 Underground	Poor	Tank is full of water and in overflow. Tank was cleaned 3 months ago. Underlying Consent requires each lot have 17 m^3 of detention draining over a 24 hour period. This requires an orifice of 11 mm.	Commercial –Lt Industrial
Tank 7 Underground	Unknown - Poor	Cannot access lid screws due to lack of maintenance and having been buried over time. Outlet is 45 mm likely to be blocked.	Large Residential Subdivision
Tank 8 Underground	Unknown - Poor	Cannot access lid screws due to lack of maintenance and having been buried over time. Outlet is 45 mm likely to be blocked.	Large Residential Subdivision
Tank 9 Underground	Unknown - Poor	Cannot access lid screws due to lack of maintenance and having been buried over time. Outlet is 45 mm likely to be blocked.	Large Residential Subdivision
Tank 10 Underground	Unknown - Poor	Cannot access lid screws due to lack of maintenance and having been buried over time. Outlet is 45 mm likely to be blocked.	Large Residential Subdivision
Tank 11 Underground	Unknown - Poor	Cannot access lid screws due to lack of maintenance and having been buried over time. Outlet is 45 mm likely to be blocked.	Large Residential Subdivision
Tank 12 Underground	Unknown - Poor	Cannot access lid screws due to lack of maintenance and having been buried over time. Outlet is 45 mm likely to be blocked.	Large Residential Subdivision
Tank 13 Underground	Unknown - Poor	Cannot access lid screws due to lack of maintenance and having been buried over time. Outlet is 45 mm likely to be blocked.	Large Residential Subdivision
Tank 14 Underground	Unknown - Poor	Cannot access lid screws due to lack of maintenance and having been buried over time. Outlet is 45 mm likely to be blocked.	Large Residential Subdivision
Tank 15 Underground	Unknown - Poor	Cannot access lid screws due to lack of maintenance and having been buried over time. Outlet is 45 mm likely to be blocked.	Large Residential Subdivision
Tank 16 Underground	Unknown - Poor	Cannot access lid screws due to lack of maintenance and having been buried over time	Large Residential Subdivision
Tank 17 Underground	Unknown - Poor	Cannot access lid screws due to lack of maintenance and having been buried over time. Outlet is 45 mm likely to be blocked.	Large Residential Subdivision
Tank 18 Underground	Unknown - Poor	Cannot access lid screws due to lack of maintenance and having been buried over time. Outlet is 45 mm likely to be blocked.	Large Residential Subdivision
Tank 19 Underground	Unknown - Poor	Cannot access lid screws due to lack of maintenance and having been buried over time. Outlet is 45 mm likely to be blocked.	Large Residential Subdivision

2.1 WETLANDS

Of the 5 wetlands examined 2 were in poor condition. The two wetlands were installed as part of the conditions of consent for an industrial subdivision. The assets had not been

maintained since they had been installed. Photos from 2012 indicate the need for maintenance at the time. Current photos from 2019 show the first wetland to be completely degraded and the second one to require significant maintenance. Pest species are prevalent in Wetland 1 and the main outlet is blocked with sediment. The forebay is also completely silted in.

Photograph 1 & 2: Wetland 1 2012 (3 years after commissioning) and present.

Photographs 3 & 4:Outlet for wetland 1 & 2 informal connection to wetland 2, 2019

Wetland 2 had two informal connections which were allowing the stormwater to bypass the forebay area completely.

The underlying failure of the wetlands is attributed to the following:

1. Developer remained disengaged in the process of designing and installing the wetlands.

2. No maintenance has occurred since installation.

3. The end users do not have any information regarding the wetlands as they were put in at resource consent stage and were to be maintained by a body corporate.

4. The regulatory body has not enforced the conditions of consent to date.

From the time of design the wetlands were likely to fail. The wetlands were viewed by the original developer as a necessary burden to get through the Resource Consent process. The developer did not view any potential for the wetlands to provide any amenity value to the property.

The current property owners have been spoken with and are now in the process of putting together a working plan to restore the wetlands. It is hoped that the group of property owners will continue to maintain the wetlands once the restoration has occurred.

Wetlands 3, 4 and 5 are located in larger residential subdivisions. The wetlands have some plastic rubbish in them. All three of these wetlands are accessible for maintenance and have walkways to provide amenity value to the surrounding community. Signage has been provided to educate visitors on both the habitat and treatment value. However wetland 5, the oldest of the three wetlands, while still being in good condition in terms of functionality, is in need of maintenance. In the deeper wetland pool, Oxygen Weed (*Lagarosiphon major*) is pervasive and the downstream area has an unidentified sheen over the water.

Photographs 5 & 6: Wetland 5

2.2 VEGETATED SWALES

Site visits to four different swales that were designed to provide treatment and convey surface flows into the stormwater network, provided varying results. Swale 1 was nearly nonexistent due to a lack of both maintenance and knowledge. During the visit to the property the occupiers of the commercial property had no knowledge of the swale. The swale was a condition of consent and designed to provide treatment of the stormwater runoff prior to it reaching an unnamed creek at the bottom of a gully.

Photographs 7 & 8: Swale 1 behind commercial development

Swale 2 is currently in good shape but is located in a residential subdivision and requires maintenance. The scruffy domes in some sections of the swale have been grouted in and then damage has occurred due to vehicular loading.

Swale 3 was in excellent condition. In this instance the owner was on board with the design and has expressed that he feels the swale adds amenity value in providing an island of bush in the middle of an urban area. The swale was clean and free of rubbish.

Photographs 9 & 10: Swale 2 Residential Subdivision & Swale 3 single lot bush swale

Swale 4 is currently in good shape and providing both gross contaminant removal as well as total suspended solid removal from 90 m of driveway. However, the property owner has expressed concerns with maintenance as well as the aesthetic value. In further discussions the owner finds the Oioi (Apodasmia similis), with which it was planted, overwhelming. Planting options have now been presented to the owner who is considering a new planting plan.

2.3 RAINGARDENS

Of the 8 raingardens visited 5 had been completely removed or paved over. The raingardens were part of the Land Use Consent conditions for a 5 lot subdivision. They were designed to provide treatment and detention for the shared driveway entering the infill subdivision. The raingardens were located on the individual lots so that each owner was responsible for maintenance. None of the initial owners currently own the property. Moreover, the requirement for the raingarden to be maintained, or the fact that there was a raingarden on the property, was not included in the consent notice on the title. The consent notice states that treatment and hydraulic neutrality must be provided.

Photographs 11 & 12: Raingardens when completed & 2019

Given that the raingardens were deemed compulsory by the Council's development engineer at the time of the subdivision, the failure for the information to appear on the consent notice is a regulatory failure. The fact that some of the raingardens were paved renders the assets not only useless but a contributing factor to increased runoff and contaminate loading.

Raingarden 6 is in good to fair condition however the overflow pipe has not been cut down to the required level and sticks up out of the ground about 700 mm. Additionally, during the site inspection the owner stated that they had no idea why this asset was required to be located on her property and was finding it difficult to maintain. In further discussion, the owner stated that the Oioi made it an eyesore and was causing the maintenance difficulties. As a result of the site visit an extensive list of planting options was given to the owner, who is now engaging a landscape company to help upgrade the asset so that it provides amenity value to the property.

Photographs 13: Raingarden 6

Raingardens 7 and 8 are located within a commercial subdivision. Raingarden 7 is in good to fair condition as parts of the raingarden are clogged with silt from recent roadworks. The contractor undertaking the roadworks failed to place silt controls in around the raingarden and stockpiled soil around it. The current condition of the raingarden is a result of lack of understanding.

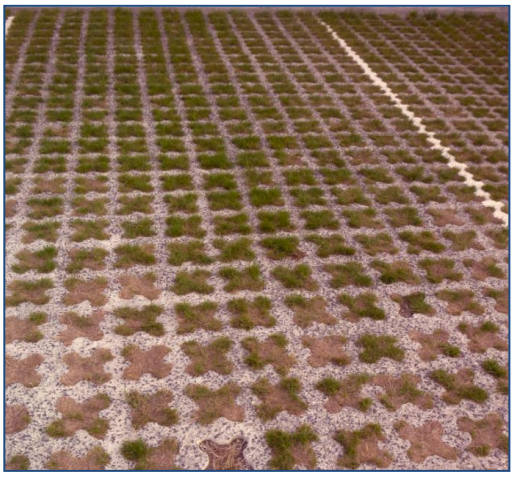
Raingarden 8 is in excellent condition. The raingarden is functioning to the design specifications and is well maintained. The business owner adjacent to the raingarden believes it adds to the streetscape in front of the entrance to the building and is pleased with it.

Raingarden 9, located in a large residential subdivision, is in need of maintenance as some of the plants have died off and rubbish is present in the gardens. The sparseness of the vegetative cover will not provide the design treatment. The rubbish as well as the plant die off detracts from some of the amenity value of the raingardens and they are less likely to be maintained over time.

2.4 PERMEABLE & POROUS PAVERS

Permeable paver site 1 is in a parking area serving a commercial building. The permeable paver used here is Grasspave™ which is poured in situ with steel reinforcement and forms to allow for grass planting within the pavement. The pavement has been in service for 3 years and traffic loading consists of 30-40 vehicle movement a day Monday – Friday. The grass component of the pavement is showing signs of stress due to summer heat; however it is likely to rebound once the rain begins again.

Photographs 14 & 15: Permeable Paving 1, Grasspave™




The property owner was questioned regarding the pavement. The permeable pavement was required as part of the consent. The owner is pleased with the product in terms of permeable paving, and feels the steel reinforcing makes it practical for commercial properties. The owner stated that the pavement it a good idea but that permeable pavement in general still requires more thought in terms of the base course. It seems to be functioning as designed and produces no runoff during small steady rainfall events but does in larger events.

Permeable paver site 2 receives most of its traffic on the weekend. The site uses two types of permeable pavers; plastic mat and Gobi blocks. The Gobi blocks have been filled with pea gravel. The pea gravel, when new, allowed the water to flow through but did nothing in terms of thermal loading. Now the pea gravel is visibly clogged. The plastic planted mat is sparsely planted and both pavers are in need of maintenance. Neither the plastic pavers nor the Gobi blocks are performing as designed.

Photographs 16 & 17: Permeable Paving 2


Permeable paver site 3 was completed to provide parking in a subdivision. The pavers used here allow water to flow between the pavers. The gaps have not been maintained and are clogged with dirt and grease. The pavers are not operating in accordance with the design.

Photographs 18: Permeable Paving 3

2.5 STORMWATER TANKS

2.5.1 ABOVE GROUND STORMWATER DETENTION TANKS

All of the above ground detention tanks were installed as a requirement of infill housing 2-3 lot subdivisions. Tank 1 was found to be operating properly and the orifice was not blocked. However tank 1 was intended to be a reuse tank and the discharge was to be to a spreader bar. Neither of the components was installed. Tank 2 was no longer functioning according to the design specifications as it was full and would overflow in any rainfall event because the orifice was blocked. Tank 3 was the only detention tank operating at design specifications. The tank was empty and there was no debris build-up in the bottom of the tank.

2.5.2 REUSE TANKS

Two reuse tanks were examined and the end users were interviewed regarding the tanks. The reuse tanks are for non-potable purposes only. Tank 4, located on a rental property, is a reuse tank with a float switch to the reticulated supply. The water from the tank is pumped into the house for laundry and toilet and also supplies water to the outside tap. The reuse tank is currently operating to the design specifications. However an interview with the end user revealed that the reuse tank had been on mains top-up for nearly 1 year as roof water was not getting into the tank due to lack of maintenance of gutters and down pipes. The renter looked up the title and obtained a copy of the consent notice which required a tank condition report be supplied to the regulatory authority but did not actually specify maintenance in the wording. It was only after the tenant went to court that the reuse system and associated gutters and downpipes were finally maintained. The tenant notes there is none of the required signage to indicate the water is for non-potable purposes only.

Tank 5, located on an owner occupied property. No automatic float switch to the reticulated supply has been fitted and it requires the owner to manually switch to the reticulated supply using a valve outside of the house. The owner finds that to be onerous and has permanently switched over to reticulated supply rendering the tank in overflow and not operating according to the design specifications.

2.5.3 UNDERGROUND TANKS

Tank 6 was the only underground tank that was accessible during the time of the research. The remaining underground tanks had their lids buried far enough in the ground that the screws holding on the lids were not accessible without destroying part of the lawns. Tank 6, located in a large (10+ ha) commercial subdivision was currently full and in overflow. The tank has been maintained within the past 6 months. The tank was a requirement of the underlying consent that each property provide 17 m^3 of detention storage draining down over a period of 24 hours. The design drawings and calculations show that this required an 11 mm orifice be installed in the bottom of the tank. It takes a small amount of debris to clog the orifice and confined space entry training to be able to perform any maintenance on the tank.

Photographs 19: Underground Tank 6

Tanks 7-19 are underground tanks located on a residential subdivision. The properties are all rental properties with a single owner. As part of the subdivision the 7000 litre underground detention tanks were installed to prevent any increase in peak flow into the combined sewer network. The design drawings indicate that each tank has a 45 mm orifice situated at the bottom of the tank. The tanks do not appear to have been maintained for some time as the lids are partially buried in the front gardens. Considering the tanks have been in the ground 10 years, and are unlikely to have had any maintenance, it is likely that all 13 tanks are in overflow.

Photographs 20: Typical Underground Tank 7-19

3 GENERAL CAUSES OF FAILURES

The field investigation has revealed that many of the WSD assets examined are absent or failing. In essence 50% have failed and are no longer providing detention or improvement of water quality. If general failures are to be identified all parties involved in the implementation of WSD must be considered:

- The regulatory body that writes the rules.
- The designers who design the assets.
- The contractors who install the assets.
- The property developer.
- The end user.
- Compliance and compliance monitoring officials.

3.1 INTENTION VS. WORDING – REGULATORY ISSUES

In examining the 40 WSD assets it was clear that maintenance was the key factor as to whether or not a particular asset failed. However upon closer inspection some of the burden must be placed upon the way in which the standards are enforced and written, as opposed to what the intention is meant to achieve. The Auckland Unitary Plan Standard E10.6.3.1.1 states "Provide detention (temporary storage) and a drain down period of 24 hours for the difference between the predevelopment and post-development runoff volumes from the 95th percentile rainfall event." According to the Technical Report 2013/035 Auckland Unitary Plan stormwater management provisions a raingarden can provide the required level of retention and detention. A continuous simulation model of raingardens in Auckland's clay soils use an infiltration rate of 2 mm/hr even though Auckland's Clay Soils typically have higher infiltration rates, even when saturated (Auckland Council 2013). Despite the previous testing Guideline Document 2017/001: Stormwater Management Devices in the Auckland Region requires that double-ring infiltrometer testing be undertaken for any site where bioretention or pervious paving is being used and retention is required. The requirement is onerous and a detention/reuse tank is the easiest most cost effective solution for the developer. However, on a residential site the small size of the orifices required to attenuate flows are subject to blocking.

3.1.1 THE USE OF TANKS

Property developers tend to view WSD assets as a burden necessary to obtain consent. Most do not view the potential of the WSD assets to provide any amenity value. During property development a detention tank or detention reuse tank is the easiest item for the council to check. Due to the perception that WSD doesn't add value a developer will put in a detention tank, the cheapest and easiest option to meet council requirements.

The renter with the reuse tank who was interviewed as part of the research went to court and took 6 months to get the property owner to maintain the tank. The renter was left with the opinion that stormwater reuse tanks do not work on rental properties. There are 34 detention and detention/reuse tanks within the subdivision the renter resides in. Almost all the properties are rentals and managed through property managers. It is more than likely that almost all the tanks are in overflow.

In terms of SMAF (Stormwater Management Area–Flow 1 & 2) mitigation, the detention/retention scenario generally results in an orifice smaller than 10 mm placed at the bottom of the detention volume on a residential site. The stormwater orifice will become quickly blocked and fail to provide the detention component of the SMAF mitigation requirements and thus the intention of the rule is not achieved.

Photographs 21: Difficult to maintain stormwater tank

Areas of Auckland served by a combined sewer network require that stormwater discharge into the system is kept to the current level. General practice is to mitigate for the 2 and/or 10 year rainfall event. It is known from the Auckland Council Safeswim Monitoring Program that sewers overflow in lower intensity rainfall events. In one area of the city served by a combined network system overflows occur about 200 times per year (C. Crosby & J. Vince 2018). The rainfall averages of the combined system overflows are closer to the 90th percentile than the 10 year event. Tanks designed for the 10 year rainfall event don't necessarily provide any mitigation for smaller more frequent events. Preventing overflows and achieving the specified outcomes of the National Policy Statement on Fresh Water will require designers and the regulatory bodies to consider retention of stormwater runoff in the combined sewer areas for smaller rainfall events such as the 95th percentile.

3.2 FAILURE IN THE DESIGN PROBLEMS

Some of the burden must be placed on the designer. An asset should be designed with both the end user and maintenance regime in mind. Requiring heavy equipment to do small maintenance tasks reduces the likelihood that the asset will be maintained. Similarly, assets located on residential lots that cannot easily be maintained by the property owner are also not apt to be maintained.

3.3 INSTALLATION ISSUES

Installation contractors do not always understand design drawings prior to installation commencing nor is certain terminology largely agreed upon. Top soil to the contractor may be the material that has been scraped of the top of the site. In a raingarden top soil is a specified mix is required to achieve performance. In addition to this contractors have been known to tell clients that money can be saved if say, a council float switch is not installed in a reuse tank, or if a gross pollutant trap is used instead of a proprietary treatment device. Worse than replacement or omission is when a contractor tells a client a particular WSD asset won't work at all. The perception that an asset won't work will result in no maintenance occurring for the life of the asset.

3.4 INFORMATION EXCHANGE FOR PROPERTY OWNERS, DEVELOPERS & END USERS

Property developers have the duty to ensure that the knowledge of the purpose and maintenance requirements of WSD assets is passed to the property owners particularly in the case of subdivisions. If the owner is not the end user it is their responsibility to pass on the relevant information to the tenants or the property manager. It is ultimately the property owner's responsibility to maintain the WSD asset.

3.5 LACK OF COMPLIANCE & COMPLIANCE MONITORING

When compliance is examined in terms of maintenance and maintaining the WSD assets on site there is no oversite by the regulatory body. Operation & Maintainance Plans may have been submitted at the consent stage, however most of the information is not being adequately recorded on the property title consent notices. Additionally there is currently no central database of the WSD assets located on private property. The regulatory body does not have the resources to ensure the thousands of WSD assets installed since the adoption of TP10 are being maintained and remain in service. Inspection and enforcement of compliance on the thousands of properties that have WDS assets is a mammoth task.

4 IMPROVING THE OUTCOME OF WSD

4.1 GREATER COOPERATION BETWEEN THE DESIGN ENGINEERS, THE DEVELOPMENT ENGINEERS AND THE STORMWATER UNIT.

Moving forward with WSD first requires that regulatory authorities work more closely with the industry professionals such as design engineers and the stormwater units. Industry professionals may often prescribe the asset most likely to gain approval by the Council development engineers rather than spending clients' money to take the time to discuss options with the development engineer and provide the asset best suited to purpose. The culture of 'us and them' between the regulatory body and the industry professionals needs to be a thing of the past if WSD assets are not going to fail at the rate revealed in the research completed herein. It is time to create transparency and not just work outside the 'silo' but to completely break it down. Industry professionals understand the importance of creating sound environmental outcomes. Greater trust and discourse between the industry professionals and regulatory authority will further those outcomes.

Is it more important an Auckland Unitary Plan standard be followed to the letter of the wording or to the intent? If there is a general acknowledgement that following the standard to the wording will cause the WSD asset to fail, it stands to reason that the intent of the standard be more closely examined. Maybe the WSD asset is designed well from a stormwater standpoint but not an end user standpoint. The regulatory authority working with the industry professionals can develop solutions that satisfy the intended outcome of the standards and will achieve longevity.

In many instances the stormwater unit inherits the maintenance of the assets being designed and installed in shared open space. Achieving better performance and maintainability where WSD assets are to be vested to the stormwater unit, requires that all the parties meet at the design phase of the project. The bringing together of design expertise and the tremendous amount of field experience held in the stormwater units can result in more effective design outcomes.

4.2 GREATER UNDERSTANDING OF PHYSICAL MAINTAINABILITY

With all developments industry professionals have a responsibility to create WSD assets that can be maintained. Forebays for wetlands need to be accessible with a standard digger. Planting plans for raingardens, wetlands and swales need to be well thought out or that may be considered an eye sore by the end user and/or become difficult to maintain. In the case of Oioi (Apodasmia similis) it is an inexpensive native that provides rapid good coverage; however, it can become unruly and some end users dislike the look of it. With the pallet of available and appropriate natives engagement with the architect, the developer and landscape designers can be key to designing an asset that functions well and provides amenity value.

In regards to stormwater tanks, which have the potential to be a useful tool industry professionals need to develop a removable orifice fitting which allows for easier maintenance. Underground tanks need to have a smaller easy to remove inset lid which completely lifts out the orifice manifold and allows for it to be quickly and easily cleaned. The current design of underground tanks results in Confined Space Entry Training being required for basic maintenance to occur. If there is to be any chance of tanks being maintained the clearing of a stormwater tank orifice needs to be as easy for the property owner as mowing the lawn even for an underground tank.

4.3 CERTIFICATION OF CONTRACTORS & SAFETY IN DESIGN

Contractors involved in installation need to be aware that there is a responsibility to contact the design engineer if there is any ambiguity in the drawing or any changes that are deemed necessary during the installation. Certifying contractors to install raingardens, vegetated swales and wetlands can produce better outcomes upon installation. Designers working with contractors can develop designs that better address safety in design. Assets need to be both easy and safe to install and easy and safe to maintain.

4.4 CATCHMENT WIDE SOLUTIONS

When exploring the prospect of a multiple lot development the developer should work with the architect and engineer to determine the best way to implement any required WSD. A good developer, engineer and architecture team will look beyond the requirements to what will provide the greatest amenity value. Is there a way to take the stormwater out of the grey infrastructure and create green infrastructure that will provide amenity value? Greener urban areas are associated with sustained mental health improvements (Alcock, et al. 2014). Research has shown that a potential buyer is willing to pay higher prices for new property close to a greenspace (R. Trojanek, M. Gluszak and J. Tanaś 2018). Creating a general green space which also serves as the water retention and water treatment device may offset the value of the land used to provide WSD. Placing raingardens along the street scape and creating larger wetlands and centralized blue-green infrastructure, rather than placing tanks on each property, will yield better results while still providing a treatment train approach.

4.5 IMPROVED COMPLIANCE MONITORING

It is not likely that the regulatory body will ever have the resources to physically monitor every property with a WSD asset; however, developing a database of the assets still believed to be in operation is possible. Developing a system that allows asset owners to easily upload maintenance records is also an achievable goal. Compliance monitoring of larger jointly owned assets also needs to be considered.

4.6 IMPROVEMENTS TO PUBLIC PERCEPTION & AWARENESS

The stormwater industry has an understanding of the 'why' of WSD assets but until the general public understands the purpose of WSD assets, it is likely maintenance failures and removal of assets will continue to occur. How do we increase public awareness in regards to WSD as an industry? Stormwater Conference 2018 paper: An Applied Stormwater Education Programme (M. Hannah & S. Neighbours 2018) demonstrated that the findings from a school run investigation reached the wider community including the City Council. Primary schools, in particular, are a grass roots resource to bring effective change. Getting children engaged in analysis and critical thinking about the environment will allow families to understand why stormwater flows need to be mitigated and why stormwater needs treatment. Developing and finding funding sources to provide curriculum around stormwater and its impact will raise community awareness and improve outcomes. Even Council Road Shows of WSD at small community events can aid in developing public awareness.

5 CONCLUSIONS

The past decade has seen a huge increase in the number and improvement in the quality of WSD assets being installed. Planting plans and soil mixtures have improved for raingardens, wetlands and swales. Permeable pavers now have a reinforced solution that is applicable to commercial sites. There is now a general adoption by designers to recommend water reuse for non-potable purposes. Still the lack of maintenance of WSD assets abides. The current overall score for the condition of WSD assets installed over the past decade is 50%. If we are to improve our urban streams, and meet the criteria of the National Policy Statement on Fresh Water Management, that score is going to have to improve.

Achieving better outcomes requires changing behavior. Looking at the underlying reasons for failures and coming away with a fault free toolbox of new behaviors designed to succeed will require:

- Greater trust and cooperation between design engineers and development engineers working for the regulatory body will result in achieving better outcomes in practice and not just in principle.
- Assets being developed with the end user in mind.
- Better maintainable designs for stormwater tank orifices.
- Consideration of safety in design for both installation and life of the asset.
- Creating a system where contractors understand both installation and the principal of WSD assets.
- Engaging developers in potentially adding value through blue-green infrastructure.
- Implementing catchment wide solutions which provide both cost value and amenity value where possible.
- Cataloguing the number and type of WSD assets currently in service.
- Creating an understanding in the general public as to why WSD assets are essential to the health of our waterways.

- Generating a desire amongst the general public and all the other participants to design, install and maintain WSD assets.

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REFERENCES

Alcock I, White MP, Wheeler BW, Fleming LE, Depledge MH**.** (2014) 'Longitudinal Effects on Mental Health of Moving to Greener and Less Green Urban Areas' *Environ*mental *Sci*ence *Technol*ogy *48*, 2, pp 1247–1255

Auckland Council (2013) Auckland Unitary Plan stormwater management provisions: Technical basis of contaminant and volume management requirements, Technical Report 2013/035

Auckland Council (2017) Stormwater Management Devices in the Auckland Region Guideline Document 2017/001 Version 1

Auckland Regional Council (1995) Auckland Regional Council technical Publication 10 (TP10)

Auckland Unitary Plan, Operative in Part (2016) Chapter E10. Stormwater management area – Flow 1 and Flow 2.

C. Crosby & J. Vince (2018) Infrastructure Renewal – Maximising Public Benefit Through Collaboration And Engagement. Water New Zealand, New Zealand Stormwater Conference Papers 2018

Hannah M and Neighbours S. (2018) An Applied Stormwater Education Programme. Water New Zealand, New Zealand Stormwater Conference Papers 2018

Trojanek, R., Gluszak, M., & Tanas, J. (2018). The effect of urban green spaces on house prices in Warsaw. *International Journal of Strategic Property Management*, *22*(5), 358-371.