FROM VISION TO REALITY: STORMWATER TREE PITS IN CENTRAL CHRISTCHURCH

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ABSTRACT

Christchurch residents have articulated a vision for their future central city to be greener and more liveable. Guidance documents released by Government agencies promote integrating stormwater treatment into the design of the public realm and this includes stormwater tree pits in the central city. Significant challenges need to be overcome before this vision can become reality however, such as construction around existing services, connecting to a shallow stormwater pipe network, maintaining overland flow paths, allowing for future maintenance and meeting tight budgetary constraints.

Christchurch City Council recently developed stormwater tree pit design guidelines to facilitate their use in Christchurch. Specimen designs were also undertaken to test the feasibility of implementing stormwater tree pits in central Christchurch. 'An Accessible City', Christchurch's central city transport framework, provides the first test for the implementation of these guidelines.

This paper presents a summary of the process of taking the vision of stormwater tree pits in central Christchurch to the detailed design phase for the Accessible City project.

Manchester Street and the Durham/Cambridge transport corridors provide a case study to show how the design challenges were overcome. A range of variations in stormwater tree pit configurations were necessary to allow for as much flexibility as possible. Stormwater tree pits were located both in on-street parking bays and behind the kerb in the footpath. In some places they were combined with rain gardens to increase the treatment area. An innovative tree pit design from Stockholm was implemented where there were clusters of trees. In other places only passive irrigation of tree pits could be achieved. The work demonstrates that where a flexible and innovative approach is adopted then stormwater tree pits are suitable for retrofit into existing urban centres.

KEYWORDS

Stormwater tree pit, bioretention, treatment, design, guidelines, case study

PRESENTER PROFILE

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1 INTRODUCTION

Stormwater tree pits (also commonly known as bioretention tree pits) are a versatile bioretention stormwater management device providing passive irrigation of street trees, stormwater quality treatment, groundwater recharge, peak flow and volume attenuation, and other significant non-stormwater benefits.

Stormwater tree pits are bioretention devices similar to rain gardens. The main difference being that stormwater tree pits contain a tree in addition to or instead of smaller plantings that are contained in a traditional rain garden. The inclusion of a tree also requires a deeper filter media layer than is required in a rain garden. Similar to rain gardens, a stormwater tree pit collects stormwater runoff from the adjacent carriageway (and other impervious and pervious surfaces) and treats this water prior to discharge to ground and/or the conventional piped stormwater network.

Christchurch City Council (CCC) is developing a Stormwater Management Plan (SMP) for the Ōtākaro/Avon River catchment, a highly urbanised catchment of 8,860 hectares. As few sites exist for large treatment devices, retrofitting smaller treatment devices into the existing stormwater network is one of the main mitigation options available. Stormwater tree pits, rain gardens and proprietary treatment devices have all been identified as potential options suitable for retrofit water quality treatment measures.

Guidance documents released by Government agencies promote integrating stormwater treatment into the design of the public realm. A key document is the Christchurch Central City Plan that provides a unified and comprehensive reference document for the design and delivery of public realm improvement projects in the central city.

As part of the Avon SMP, CCC developed stormwater tree pit design guidelines as part of the toolbox of stormwater treatment measures suitable for retrofitting in Christchurch. Specimen designs were also undertaken to test the feasibility of implementing stormwater tree pits in central Christchurch. *An Accessible City* (CERA, 2013), Christchurch's central city transport framework, provides the first test for the implementation of these guidelines.

Some example urban stormwater tree pits are presented in Figure 1**.**

Figure 1: Example Stormwater Tree Pits

University of Sydney

Waitangi Park, Wellington

2 THE VISION

Runoff from public areas in the central city of Christchurch discharges untreated into the Ōtākaro/Avon River. The rebuild of the central city offers an unprecedented opportunity to retrofit stormwater treatment in order to improve water quality in this iconic waterway.

Previously stormwater treatment and landscaping/amenity have been separated and considered as two separate areas of operation. The current work to develop a contemporary urban palette for Christchurch and to repair damaged infrastructure presents an opportunity to re-integrate stormwater management with landscape, mimicking how nature deals with stormwater.

For the Christchurch central city, stormwater tree pits offer the opportunity to treat stormwater runoff at source from the smaller street-scale sub-catchments. Tree pits will not only provide stormwater quality treatment as stormwater passes down through the soil medium, but also reduce the magnitude and frequency of stormwater runoff entering receiving waterways such as the Ōtākaro/Avon River.

In addition to the stormwater benefit, these trees provide multiple other benefits, such as improving amenity, providing shade, reducing temperatures, absorbing carbon dioxide etc. This paper focuses on the stormwater benefit, but it is often these other benefits which provide the economic and social drivers to introduce street trees. It is considered that stormwater benefits alone are insufficient to persuade decision makers to invest in street trees when more economic means of stormwater treatment exist.

Two projects were critical to the development of the vision for stormwater tree pits in Christchurch: *An Accessible City* (CERA, 2013) and the Avon SMP. These are described in more detail in the sections following.

2.1 AN ACCESSIBLE CITY

When CCC asked people after the earthquakes to present their ideas about the central city recovery, there were more than 100,000 ideas shared. Advice also came from professional institutes, interest groups and community organisations. Out of all the ideas shared five key themes emerged, one of which was a 'green city'. Two key aspirations noted under this theme were:

- New street trees, improved surface stormwater treatment and a new network of parks that encourage outdoor activities.
- A greener, more attractive central Christchurch, which includes measures against climate change.

Stormwater tree pits are one way to meet these aspirations.

An Accessible City (CERA, 2013) is one of a number of planning documents which articulates how the aspirations of a green city could be translated into reality. *An Accessible City* (CERA, 2013) presents road use hierarchy plans and typical road corridor cross sections to be considered in the city through the 'Accessible City' project. Figure 2 presents a typical 'Main Street' prioritised cross section which includes street trees within the on-street parking bay locations.

The authors of this paper took part in the two design teams that were engaged to translate the concepts within *An Accessible City* (CERA, 2013) into reality. The lessons learnt reported in this paper are based on the challenges and opportunities encountered during that process.

Figure 2: Typical 'Main Street' Prioritised Road Cross Section (Source: CERA, 2013).

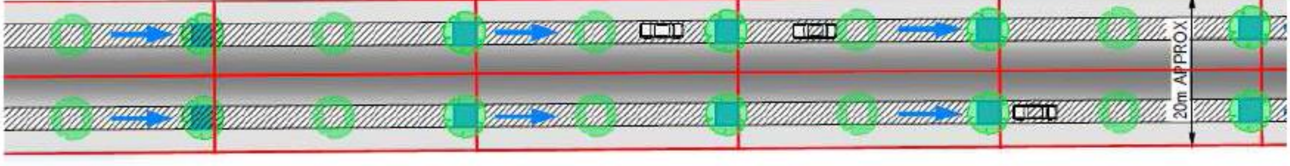
2.2 AVON STORMWATER MANAGEMENT PLAN

The Avon Stormwater Management Plan (SMP) has developed a blueprint for stormwater treatment in the highly urbanised area of the Ōtākaro/Avon River catchment. Retrofitting smaller treatment devices into the existing stormwater network is one of the main mitigation options available. Stormwater tree pits, rain gardens and proprietary treatment devices have all been identified as potential options suitable for retrofit water quality treatment measures.

The use of stormwater tree pits is one of the preferred treatment methods in the central city because they are consistent with the street tree landscape strategy in *An Accessible City* (CERA, 2013). *An Accessible City* (CERA, 2013) proposes that street trees should be included on both sides of carriageway upgrades where existing engineering constraints make their inclusion technically and financially viable.

Intial concept work in the Avon SMP using the typical street cross-sections in *An Accessible City* (CERA, 2013) showed that street trees would typically be located in on-street parking bays at a spacing of approximately 20 – 30m. Figure 3 presents a schematic of stormwater tree pits located at 35m spacing within a central city street.

Figure 3: Potential Stormwater Tree Pit Layout in Central City Street



This initial concept work was further developed through a number of specimen designs to test the feasibility of implementing this concept in central Christchurch. Specimen designs were undertaken for a selection of streets, with a range of proposed road use hierarchies as identified in *An Accessible City* (CERA, 2013). These specimen designs included Victoria Street, Hereford Street, Manchester Street, Montreal Street, Cashel Street and Park Terrace. The specimen designs showed that stormwater tree pits would be viable in a large number of these areas, but some streets had too many underground services to make street trees (and hence stormwater tree pits) viable without expensive service relocations.

The specimen designs quickly identified that significant challenges need to be overcome to make stormwater tree pits viable, such as construction around existing services, connecting to a shallow stormwater pipe network, maintaining overland flow path capacity, allowing for future maintenance and meeting tight budgetary constraints.

The specimen design work was used to develop a design guideline, *Stormwater Tree Pit Design Criteria* (CCC, 2014). The next section describes the key design parameters and decision-making process from this guideline.

3 DESIGN GUIDELINES

3.1 CCC STORMWATER TREE PIT GUIDELINES

A design guideline, *Stormwater Tree Pit Design Criteria* (CCC, 2014) was developed as part of the Avon SMP process and tested for a range of specimen designs in central Christchurch. Some key stormwater tree pit design criteria are summarised in Table 1. A more comprehensive description of stormwater tree pit design criteria can be found in that document.

Table 1: Summary of Key Stormwater Tree Pit Design Criteria

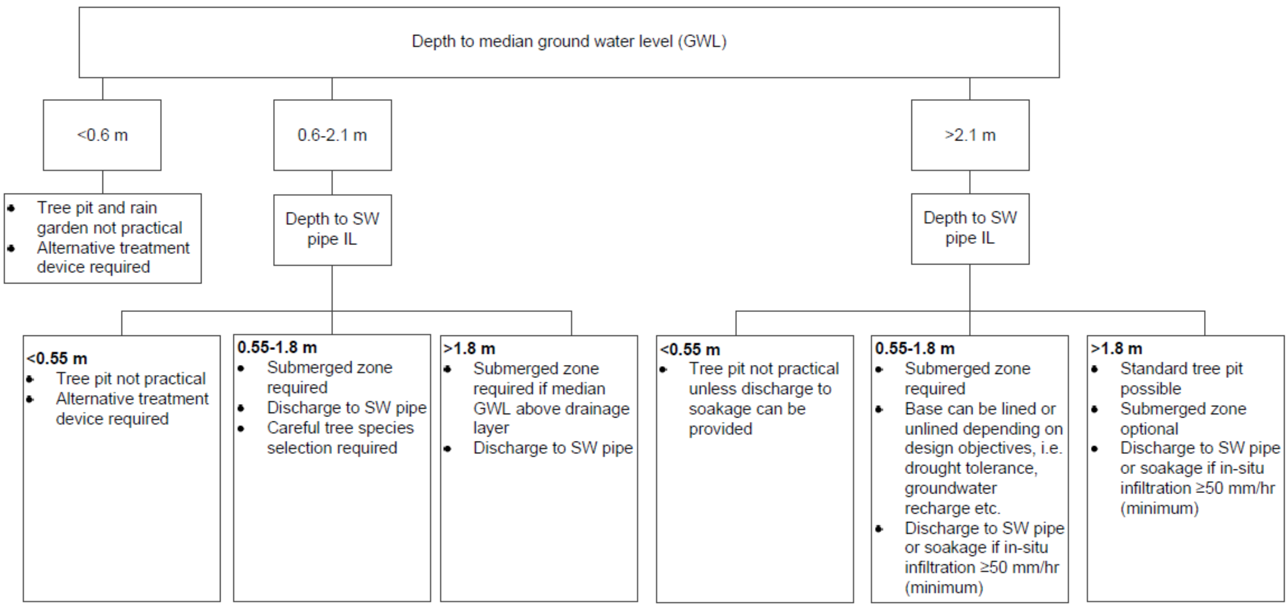
Criteria	**Description**
Extended Detention Depth (EDD)	Adopt an EDD of 150mm for stormwater tree pits in the CBD and 300mm can be considered in suburban areas. In areas constrained by shallow stormwater pipes, the EDD can be reduced to a minimum depth of 100mm.
Tree Pit Spacing	As required to achieve stormwater treatment targets. Where numerous street-scale devices is not possible, a larger device should be located at the downstream end and mid-block location where possible.
Tree Pit Dimensions	Stormwater tree pits shall be 3.5 x 3.5m in size with a minimum planting depth of 1.5m in accordance with recommendations from the City Arborist. In areas where a 3.5 x 3.5m tree pit cannot be adopted due to infrastructure constraints such as existing services, a rectangular tree pit can be adopted that maintains the same soil volume.
Media Depth	Ideally 1.5m deep, but 1.0m minimum.
Separation to Median GWL	A minimum 0.5m separation to median groundwater level from the base of stormwater tree pit is recommended. Seasonal fluctuations in groundwater levels should be considered whilst designing stormwater tree pits.

Criteria	Description
Submerged Zone	Include a submerged zone in stormwater tree pits when the depth of existing stormwater infrastructure (required to receive treated stormwater flows) is shallower than the minimum stormwater tree pit depth or when a submerged zone is considered beneficial for tree health.
Surface Treatment	The surface of stormwater tree pits shall be planted with typical rain garden plantings. Tree covers should be avoided where possible.
Maintaining Overland Flow Path Capacity	Overland flow paths on roads must have adequate capacity to convey and/or store flows beneath the finished floor level of adjacent developments for the 2% AEP design event.
Sediment Load Management	All new streetscape projects with stormwater tree pits and rain gardens included must consider construction stage sediment loads.

As previously discussed there are some key design constraints that need to be considered for stormwater tree pits in central Christchurch, including construction around existing services, connecting to a shallow stormwater pipe network, shallow groundwater levels, maintaining overland flow path capacity, allowing for future maintenance and meeting tight budgetary constraints. These constraints were identified from the stormwater tree pit specimen designs undertaken.

Whilst engineering solutions can be found for some of these constraints, some constraints may prevent the use of stormwater tree pits from being physically viable. Two critical constraints in Christchurch are depth to median groundwater level and shallow stormwater pipe networks. A flow chart has been prepared to assess the viability of stormwater tree pit use within Christchurch and assist designers identify the most appropriate configuration of the tree pit. This flow chart is presented in the *Stormwater Tree Pit Design Criteria* (CCC, 2014) report and reproduced in Figure 4.

Figure 4: Stormwater Tree Pit Design Flow Chart

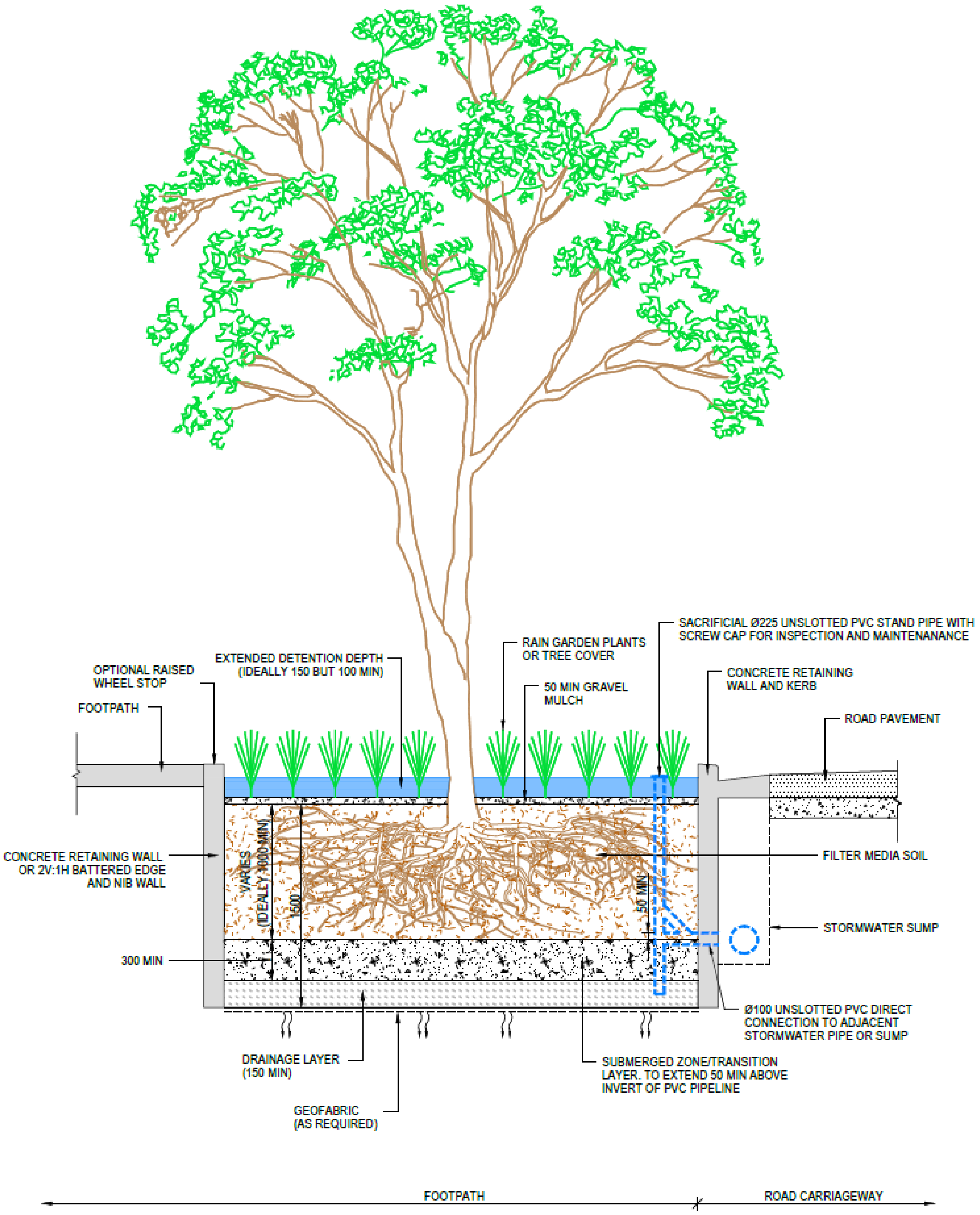


These potential constraints need to be identified early on in a project to determine the viability of the use of stormwater tree pits and other bioretention devices, such as rain gardens.

3.2 TYPICAL STORMWATER TREE PIT CONFIGURATION

Figure 5 presents a typical stormwater tree pit that is located behind the kerb alignment and intended as a small street-scale device. This tree pit comprises a submerged zone outlet to allow connection to a stormwater network shallower than the tree pit depth.

Figure 5: Typical Stormwater Tree Pit Configuration



The configuration of a stormwater tree pit will vary significantly from site to site due to site specific engineering constraints and the location of the stormwater tree pit within the carriageway. The *Stormwater Tree Pit Design Criteria* (CCC, 2014) report presents some typical configurations for stormwater tree pits and passive irrigation tree pits located both behind the kerb alignment and within the on-street parking bay (with various cross fall directions). These details may need to be adjusted to suit the individual design.

3.3 THE 'COMMONS' TEST SITE

Given that bioretention devices (rain gardens and stormwater tree pits) had not been commonly used in Christchurch prior to the rebuild of the city, Christchurch specific filter media mixes had not been investigated.

Various filter media mixes are presented in both New Zealand and international guidelines which are based on local climatic conditions, local plant species and commonly available materials in the location the guidelines were developed. Location specific media mixes should only be adopted elsewhere after their long-term hydraulic and pollutant removal performance has been tested, when equivalent materials are available to achieve the same design criteria and if they are suitable to sustain healthy plants.

Due to the lack of local data on filter media mixes, the CCC *Rain Garden Criteria for Cost Effective Design* (CCC, 2013) and *Stormwater Tree Pit Design Criteria* (CCC, 2014) reports identified that the NZTA (2010) or FAWB (2009) guidelines could be used but further investigations were required to identify the best media mixes to be used in Christchurch.

To facilitate better understanding of what filter media mix is most suitable for Christchurch, Gap Filler and CCC have installed a demonstration rain garden at the 'Commons' site in the central city (previously the site of the temporary 'Pallet Pavilion'). Figure 6 presents the demonstration rain garden site at the 'Commons'. Construction was completed in October 2014 so the plants and trees are currently becoming established.

CCC is using these rain garden and stormwater tree pit cells to test several different filter media mixes to determine which are most suitable for Christchurch conditions. Different plants are also being trialled to see how well they grow in different filter media mixes. The suitability of locally available material specifications and pollutant removal efficiency of suspended solids, metals, nitrates and phosphorus is also being tested, with continuous data sampling of storm events being carried out. A structural soil mix for stormwater tree pits is also being tested for potential use adjacent to road carriageways.

Whilst it is too early to provide a summary of the outcomes from this test site, initial results are looking positive and will be used to influence the design of bioretention devices in ongoing and future projects within Christchurch.

The demonstration rain garden and stormwater tree pits have already demonstrated the ability to achieve design infiltration rates in locally available filter media mixes and which rain garden plant species will grow well in local conditions. It has also provided valuable information for the specification of structural soil media and material specifications to ensure bridging criteria between separate layers (in stormwater tree pits and rain gardens) are achieved.

Figure 6: Demonstration Rain Garden at the 'Commons' in Christchurch

Two stormwater tree pit cells have been included and are located at the furthest end of the photo.

4 THE REALITY

An Accessible City (CERA, 2013) provides a framework to create a central city transport system that will be flexible and resilient. Design of the first set of key transport corridors was awarded to two design teams. One, City [*] Sense, is an alliance between Aurecon, URS and Jasmax. The second team consists of CCC designers. This section reflects some of the lessons learnt by stormwater engineers from both teams through that design process.

4.1 AN ACCESSIBLE CITY: MANCHESTER STREET AND DURHAM/ CAMBRIDGE TRANSPORT CORRIDOR

Manchester Street is envisioned as a tree lined boulevard to strengthen the city's green infrastructure network and provide an environment that can accommodate a busy bus corridor. It will have five to seven storey mixed use and residential development on both sides. The Manchester Street corridor will interface with the Avon River Park, Margaret Mahy Family Playground, the East Frame and Innovation Precinct.

The Durham/Cambridge transport corridor is envisioned as a green parkway section that is influenced by its interface with the Avon River Park, and particularly the Park of Remembrance section between Gloucester Street and Cashel Mall, which is curvilinear in its alignment. This section will accommodate two lanes of traffic, two-way separated cycle paths and a pedestrian pavement.

4.2 DESIGN CHALLENGES

To integrate stormwater treatment into the urban amenity of the public realm through stormwater tree pits significant challenges need to be overcome before this vision can become reality. The Manchester Street and Durham/Cambridge transport corridors provide a case study to show how these design challenges were overcome.

These two transport corridors have been selected as they both have different engineering challenges arising from their constraints and these are representative of typical streets in the central city and suburban areas of greater Christchurch.

This section discusses the design challenges faced and the following section discusses the solutions adopted to overcome these challenges.

4.2.1 PHYSICAL CONSTRAINTS

CHALLENGES

The Manchester Street corridor is located to the east of the CBD near the boundary of the Avon and Heathcote River catchments. There is an existing piped stormwater network that runs along Manchester Street in a northerly direction before discharging into the Avon River. This results in the existing stormwater network comprising shallow stormwater pipes which are located immediately beneath the kerb and channel and protected by a concrete surround. The scope of the project did not allow for re-laying the stormwater network at a greater depth.

The Durham/Cambridge corridor is located to the west of the CBD adjacent to the Avon River. There is limited existing piped stormwater infrastructure along the Durham/Cambridge corridor alignment, but deeper stormwater pipes are located at all cross roads prior to discharging into the Avon River.

The key physical constraints for both of these study areas are presented in Table 2.

Table 2: Summary of Key Physical Constraints

Constraint	Description of constraint
Existing shallow stormwater pipes (primarily on Manchester St)	This impacts the depth of filter media that can be adopted and required a modified design with a shallower extended detention depth (EDD) and filter media depth. In-situ ground conditions comprise poorly drained material that is not suitable for discharge to ground via infiltration/soak pits.
Construction around existing underground services	The existing road carriageways have extensive existing services such as water reticulation, wastewater, stormwater, gas and multiple telecommunications cables. The project budget did not allow relocation of existing services and stormwater treatment devices had to be located between existing services, with adequate protection provided to prevent damage of services.
Construction of treatment devices adjacent to road carriageways	Stormwater tree pits, rain gardens and the adjacent carriageway needed to be protected from damage.
Maintaining overland flow path capacity	As Christchurch is flat and street trees are generally in on-street parking bays, it was important to make sure that adjacent properties were not subjected to increased flooding vulnerability.

Constraint	Description of constraint
Shallow groundwater levels	Large areas of the Manchester Street and Durham/Cambridge corridors have median groundwater levels greater than 2m below existing surface levels but some isolated areas have median groundwater levels as shallow as 1m. Seasonal fluctuations in groundwater level of up to 0.5m occur in these areas. This influences the suitability of bioretention devices in some areas and influences the design configuration in others to ensure that the minimum separation between groundwater levels and the base of bioretention device is achieved.
High sediment loads during construction of the city rebuild	Bioretention devices need to be protected from high construction sediment loads that could arise from the redevelopment of sites adjacent the road corridors.
Vehicle, cyclist and pedestrian safety	The design of stormwater tree pits and rain gardens needs to consider the safety of other all modes of transport within the transport corridor such as vehicles, cyclists and pedestrians.

SOLUTIONS

A range of stormwater tree pit configurations were developed to accommodate the various engineering constraints, with the most critical being connection to shallow stormwater pipes, shallow groundwater levels and construction of tree pits between existing underground services.

Table 3: Solutions to Key Physical Constraints

Constraint	Solution
Existing shallow stormwater pipes (primarily on Manchester St)	The EDD was reduced to 100mm to allow shallow bioretention devices to be included in Manchester Street. Stormwater tree pits were designed with a submerged zone to allow connection to a stormwater pipe that is shallower than the depth of the tree pit media. Careful tree species selection was required to ensure they could tolerate these growing conditions. Shallow rain gardens were adopted in many locations. These rain gardens comprised a reduced filter media depth to allow all bioretention device layers to fit between the kerb invert and shallow stormwater pipe invert levels. The use of shallow rain gardens with street trees incorporated into the rain garden footprint was also adopted. This design allows increased ponding storage and passive irrigation benefits. In these devices the rain garden media and conventional tree pit structural soil will be separated by an internal root barrier.
Construction around existing underground services	A rectangular footprint was typically adopted for stormwater tree pits to ensure they could be constructed between existing services adjacent the on-street parking bay and maintain the minimum tree pit soil volume as specified by the City Arborist.

Constraint	Solution
	The relocation of kerb alignments on Manchester Street and the eastern kerb of Cambridge Terrace allowed the location of tree pits and rain gardens to miss areas with extensive underground services.
Construction of treatment devices adjacent to road carriageways	Stormwater tree pits will be located behind the kerb alignment in locations where street trees are proposed and engineering constraints allow stormwater tree pits to be used. This approach was achieved for the Manchester Street and eastern Cambridge Terrace kerb alignments as they were being realigned. Vertical retaining walls will be adopted for stormwater tree pits located adjacent to the carriageway. Where possible a battered edge will be adopted within stormwater tree pits and rain gardens to minimise the extent of retaining walls and reduce costs. Adjacent services, carriageway and footpath surfaces will be protected from root damage using retaining walls and root barriers. The inclusion of submerged zones and appropriate tree species selection will encourage tree roots to grow down rather than spread beneath the carriageway in search of water.
Maintaining overland flow path capacity	Where possible stormwater tree pits and rain gardens will be located behind the kerb alignment which will allow high flows to bypass the device. Other solutions include grading the on-street parking bay carriageway towards a concrete dish drain that flows along the front of bioretention devices, and kerb openings upstream and downstream of passive irrigation tree pits constructed within standard on-street parking bays graded towards the kerb. Refer Section 4.2.4 for further discussion.
Shallow groundwater levels	Stormwater tree pits and rain gardens will only be located in areas where the separation between the median groundwater level and the base of the device meets CCC criteria. Consideration of seasonal and annual fluctuations in groundwater level was considered when siting treatment devices.
High sediment loads during construction of the city rebuild	A combination of measures have been adopted to minimise the likelihood of filter media porosity being reduced from high sediment loads during construction such as the use of small sediment forebays, weed mat and locating inlets to combined devices away from filter media where possible.
Vehicle, cyclist and pedestrian safety	A low EDD, battered edges and dense planting will be adopted to minimise the likelihood of injuries to pedestrians, cyclists and motorists.

4.2.2 COST EFFECTIVENESS

CHALLENGES

The inclusion of stormwater tree pits in the central city is generally only considered to be economically viable in areas where street trees will be included. Preliminary cost estimates have predicted an incremental increase in capital cost for a stormwater tree pit over a standard tree pit of approximately 20% where suitable economies of scale exist (e.g. multiple stormwater tree pits installed on one street).

SOLUTIONS

The following design strategies have been adopted to reduce construction costs of stormwater tree pits:

- Only including stormwater tree pits in areas where street trees will be included, with rain gardens used elsewhere as they are more cost effective.
- Installing stormwater tree pits only where they are able to easily connect to the existing network, as the cost of extending the network is high.
- Reducing the cost of individual stormwater tree pits by using battered edges and structural soil media rather than retaining wall edges if possible.
- Using locally available materials that are familiar to contractors.
- Providing direct connections from commercial roofs to the piped stormwater network where possible to reduce the catchment area and therefore size of the to bioretention devices (as treatment of stormwater runoff from roofs is not required by CCC).

4.2.3 MAINTENANCE

CHALLENGES

Typical maintenance considerations for bioretention devices were reported on in CCC's stormwater tree pit (CCC, 2014) and rain garden (CCC, 2013) design criteria reports.

The authors of this paper took part in meetings within CCC operations staff to discuss maintenance concerns for stormwater tree pits and develop solutions to address potential issues. The main concerns identified were:

- The procedure to rejuvenate the porosity of stormwater tree pit media due to compaction over time and accumulation of sediment (given that CCC and the community are unlikely to accept having established trees removed).
- Accumulation of contaminants and therefore the ability to comply with any Resource Consent requirements.
- Root intrusion into the underdrains and risers.

Appropriate maintenance solutions were investigated and also discussed with authorities that commonly use stormwater tree pits such as Auckland Transport and the City of Melbourne Council.

SOLUTIONS

A range of solutions were identified, and it was considered that when used together they will provide sufficient options to address potential future maintenance issues.

Firstly, provision was made for refurbishment of the upper 100mm of media in stormwater tree pits by selecting species which can cope with periodic removal of this upper layer. Other authorities that use stormwater tree pits consider this viable. Testing to confirm the impact of this on trees are currently being considered.

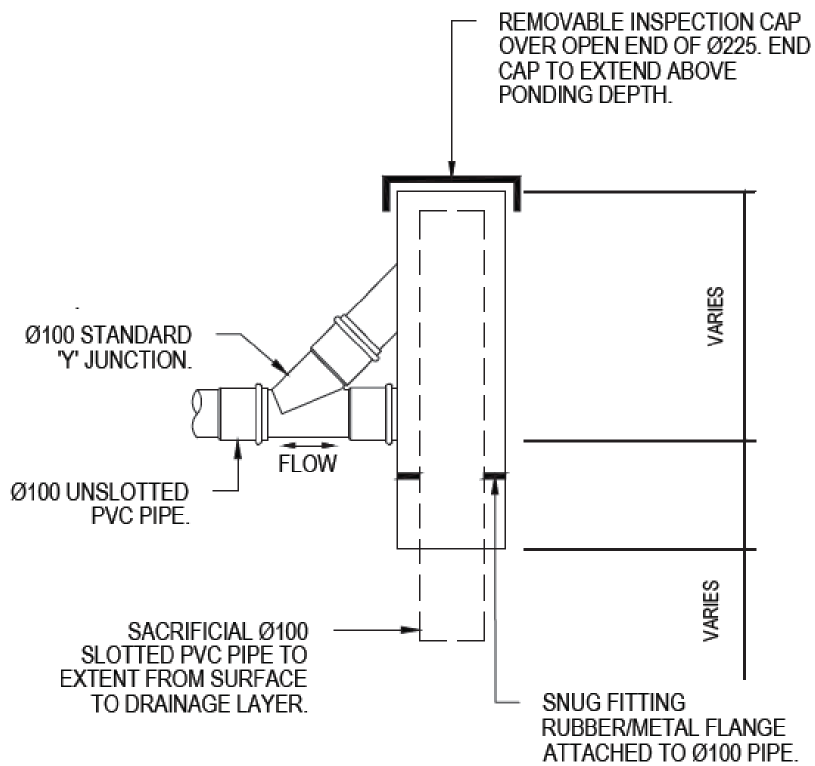
Another recommendation is to plant stormwater tree pits with smaller rain garden plantings as these plant species typically have active root growth and die-back and this provides capillary voids to help maintain porosity of media.

Use of suitable weed mat materials and/or sediment forebays will help to minimise the accumulation of sediment over filter media, preventing premature clogging.

CCC staff were concerned about the risk of underdrain blockage due to tree root intrusion in stormwater tree pits. The primary concern is that once installed, the underdrain can't be replaced because established street trees are unlikely to be removed. Whilst there are design procedures to minimise the likelihood of tree root intrusion, CCC have developed a sacrificial riser design to provide an additional level of protection.

The sacrificial riser design comprises a sacrificial 100mm diameter PVC pipe within an external 225mm diameter permanent PVC pipe. In the event of tree root intrusion into the riser (more of a concern for risers in devices with a submerged zone), the 100mm diameter sacrificial riser (and tree roots) can be removed by maintenance staff with a hand auger and replaced. A standard riser and sacrificial riser schematics are presented in Figure 7.

Figure 7: Sacrificial Riser Typical Detail



4.2.4 MAINTAINING OVERLAND FLOW PATH CAPACITY

CHALLENGES

In central Christchurch the grade is generally very flat and commercial floor levels are only marginally above footpath level. Therefore it is important that the overland flow path capacity of streets is maintained for events up to the 2% AEP design event in accordance with CCC requirements.

SOLUTIONS

A range of strategies were adopted for the 'An Accessible City' project to ensure overland flow path capacities were not adversely impacted.

First, stormwater tree pits and rain gardens were located behind the kerb alignment where possible to allow stormwater to enter and bypass individual devices with kerb openings in the kerb nib. This approach can typically be achieved in areas where the kerb alignment will be adjusted. Construction of bioretention devices behind an existing kerb alignment was not usually possible due to the large number of services beneath the footpaths in this area. The relocation of kerb alignments on Manchester Street and the eastern side of Cambridge Terrace allowed stormwater treatment devices to be located behind the kerb alignment.

The second strategy was to construct stormwater tree pits and rain gardens in the on-street parking bay and to grade the on-street parking bay away from the existing kerb alignment to a concrete channel located between the carriageway and on-street parking bay. This allows stormwater runoff to bypass along the front of treatment devices when their capacity is reached. This approach was adopted for large areas of the Manchester Street alignment.

Where possible the carriageway width between kerb alignments was not reduced. The carriageway width was only reduced in areas in which overland flow magnitudes could be adequately conveyed within a narrower carriageway width, as determined through hydraulic analysis.

Another option was to construct tree pits in on-street parking bays as passive irrigation tree pits with provision for stormwater runoff to pass through upstream and downstream kerb openings. Passive irrigation tree pits are discussed further in Section 4.2.6.

The adoption of the above strategies will ensure that stormwater tree pits will not have a negative impact on flooding vulnerability for adjacent developments.

4.2.5 ACHIEVING STORMWATER TREATMENT TARGETS

CHALLENGES

Stormwater tree pits and rain gardens need to be sized to capture 80% of stormwater runoff volume in accordance with CCC guidelines, which equates to capture of the 20mm first flush depth. The methodology used to arrive at these figures is described in Christensen et. al. (2014).

It was difficult to achieve this stormwater treatment target for the 'Accessible City' corridors for the following reasons:

- The large extent of underground services minimises the area that is available to locate stormwater treatment measures without costly service relocations.
- The need to maintain a lower EDD in the central city (150mm) than suburban areas (300mm) increases the footprint of bioretention devices.

- Shallow stormwater pipes on Manchester Street restrict the EDD that can be achieved to 100mm in bioretention devices. Whilst this reduces the safety hazard of a large drop into bioretention devices, a stormwater tree pit with 100mm EDD needs to be three times the size of a device with 300mm EDD when sized to capture the water quality volume.

SOLUTIONS

The above constraints resulted in the need to develop an alternative standard to design stormwater tree pits and rain gardens to be retrofitted into the 'Accessible City' corridors.

Discussion with CCC identified a tiered approach to sizing stormwater treatment measures to be retrofitted into existing central city streets with challenging constraints to overcome. This approach is summarised below:

- Where possible size rain gardens and stormwater tree pits to capture 80% of stormwater runoff volume.
- If the above target is not viable, size treatment measures to capture at least 75% of total suspended solids (TSS) using a measure such as continuous simulation water quality modelling or equivalent.
- If the above target is not viable, design street trees as passive irrigation tree pits.

Bioretention devices in the 'Accessible City' corridors have been sized to remove 75% of TSS loads using the MUSIC continuous simulation water quality software developed by eWater in Australia. The MUSIC model has been calibrated to Christchurch specific conditions and the reduction in concentration and load of TSS and heavy metal pollutants has been estimated. The use of MUSIC for sizing stormwater treatment measures in Christchurch will be discussed further in a future paper.

4.2.6 PASSIVE IRRIGATION TREE PITS

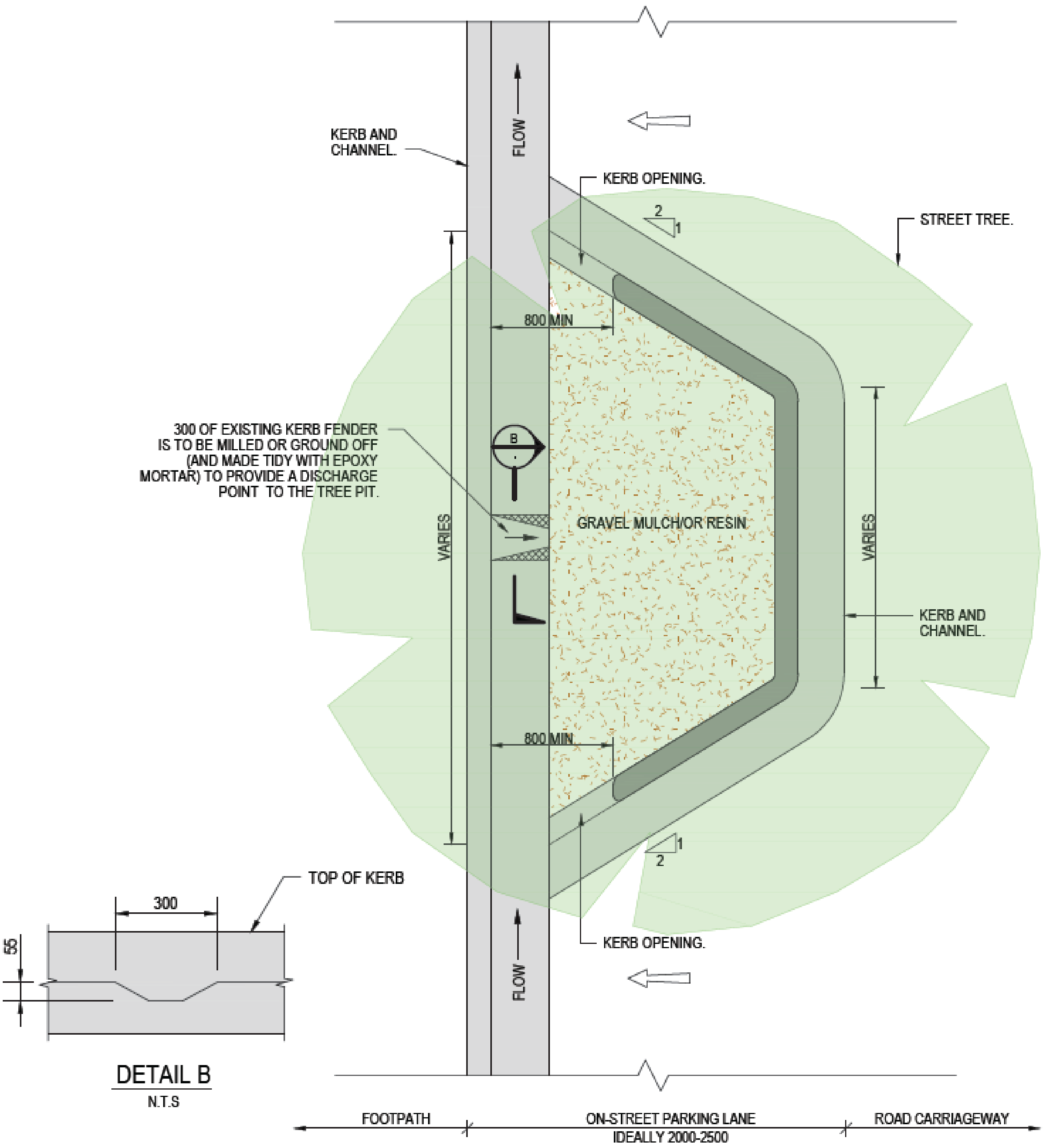
Street trees that will not be constructed as stormwater tree pits have been designed as passive irrigation tree pits where possible. Passive irrigation tree pits are defined as a tree pit in which the surface is lower than the bottom of the kerb channel so that the first portion of runoff enters the tree pit to irrigate the tree and provide some stormwater treatment.

The authors worked closely with CCC to develop standard passive irrigation tree pit designs that can be constructed in raised build-outs within the on-street parking bay. The passive irrigation tree pit configuration adopted is presented in Figure 8.

Passive irrigation tree pits are ideal between stormwater treatment devices at the downstream end and mid-block locations of carriageway sections. These trees are being constructed in the on-street parking bay which also functions as the overland flow path, and therefore must be designed to ensure flow paths are not impacted.

In Christchurch's central city the passive irrigation tree pits have a 50mm EDD and a resin bound aggregate surface. This surface treatment has been chosen to prevent the need to maintain plants in a large number of build-outs, and ensure that overland flow paths are not blocked by dense vegetation. The resin bound aggregate surface could be retrofitted with plants in the future to improve the treatment capability and the long-term permeability. The shape of the build-out has been adopted to facilitate maintenance by street sweepers. The width of the kerb opening on the kerb alignment can be adjusted to accommodate overland flow path requirements.

Figure 8: Typical Passive Irrigation Tree Pit Configuration



5 CONCLUSIONS

When Christchurch residents were asked to comment on how they wanted their city to be rebuilt, some of the common things mentioned were a greener city, trees and stormwater treatment. Stormwater tree pits address all these things, but retrofitting them into a central city environment is not without its challenges.

However, by adopting a flexible design and through careful consideration of the design challenges, stormwater tree pits have been shown to be viable in locations throughout the city. It is important to realise, however, that flexibility also must extend to being willing to acknowledge that stormwater tree pits are not suitable for all locations, and that other measures, such as passive irrigation tree pits, may need to be installed instead.

At the time of writing this paper, the authors were part way through detailed design of stormwater treatment measures for the 'Accessible City' project. Whilst the stormwater treatment strategy has been prepared, engineering constraints identified and appropriate solutions developed, the final design may change as detailed design is finalised. The authors hope to report back at future events on the installation of stormwater tree pits in Christchurch and how the design has continued to develop over that time.

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