AN ALTERNATIVE TO STORMWATER PONDS

Andrés Roa *–Director, AR Civil Consulting Ltd, Auckland*
Chris Stumbles *– Team Leader, Stormwater Planning –Central, Auckland Council*
Tom Mansell *–Stormwater Projects Engineer, Auckland Council*
Jack Turner *– Civil/Environmental Engineer, AR Civil Consulting Ltd, Auckland*
Greg Edwards *– Civil/Environmental Engineer, AR Civil Consulting Ltd, Auckland*

ABSTRACT

A stormwater pond was constructed by a private development company in 2004 at Carol Lee Place, Albany Heights, Auckland in order to meet stormwater quality, extended detention and peak flow attenuation objectives for a 2.97 hectare residential catchment. The pond has since failed to perform to the required standards and is undersized to achieve the required stormwater management objectives and meet consent conditions. In 2010 the former North Shore City Council undertook a detailed evaluation of the existing pond and identified a number of options for its redevelopment. The main constraint was limited space within the existing drainage reserve for the construction of a fully compliant device. Five alternative options were identified and assessed, with Option 4 determined to be the best practicable option. This concept incorporated a raingarden overlaying an underground modular crate-type detention tank system. This solution is a unique device that is able to achieve the required stormwater management objectives to the greatest practicable degree. The concept has since gone through a detailed design process and planned for construction in March and April 2012. It is anticipated that the system will have wide-reaching implications and could be replicated in similar situations throughout the Auckland region and beyond.

KEYWORDS

Rehabilitation, raingarden, crate detention tank, extended detention, permeability, hydraulic conductivity, retrofit, stormwater pond

PRESENTER PROFILE

Andrés Roa, BE (Civil) IPENZ CPEng IntPE, is a director of AR Civil Consulting Ltd, a civil engineering consultancy firm based in Takapuna, Auckland. Andrés has over fifteen years post-graduate experience in the fields of three waters and roading infrastructure, with particular emphasis on stormwater management.

1 INTRODUCTION

A stormwater management pond was constructed by a private developer at the bottom of Carol Lee Place, Albany Heights, Auckland in 2004 for the purpose of meeting stormwater quality, extended detention and peak flow attenuation objectives for a 2.97 hectare residential catchment. Increases in the density of development within this catchment since the stormwater management system was constructed have resulted in the pond becoming significantly undersized to achieve the intended functional objectives. In 2010 the former North Shore City Council (NSCC) undertook a detailed evaluation of the existing pond and identified a number of options for its redevelopment.

The main constraint for the development of a fully-compliant device was the limited space within the existing drainage reserve, in addition to moderately steep topography and the presence of residential dwellings in close proximity to the pond.

This paper presents a summary of the options assessment and a description of the selected option, which entailed a space-efficient device incorporating a dual-function detention tank / raingarden system. Five options were examined for the redevelopment of the Carol Lee Pond, which included:

1) A technically optimum pond, which extended beyond the drainage reserve and on to the adjoining recreational reserve;
2) A 'detention only' pond, also extending beyond the confines of the drainage reserve;
3) An optimized existing pond within the current pond footprint;
4) A hybrid system involving a modular underground tank overlain by a modified raingarden device; and
5) A pond with vertical sides within the drainage reserve boundary.

Further details of each option are discussed in **Section 4** of this paper. Option 4, which incorporated a modified raingarden overlaying an underground modular 'crate-type' detention tank system was selected as the preferred option for the redevelopment. This solution resulted in a unique device which combined the superior water quality performance of a raingarden while making use of the efficient storage volume afforded by underground detention tank modules, combining to achieve the desired stormwater management objectives.

2 BACKGROUND

In 2002, NSCC and the former Auckland Regional Council (ARC) granted resource consents to construct a stormwater management pond off of Carol Lee Place, Albany Heights, as part of the overall stormwater management requirements for a 35 lot residential subdivision development. Subsequent variations to these consents were granted which impacted on the extent and make-up of the contributing catchments, and the sizing and performance of this pond. **Figure 1** below shows the location of the device in the context of the surrounding roads.

Field investigations and desktop analyses have demonstrated that the current Carol Lee pond failed to perform to the required standards and was insufficiently sized to achieve the minimum stormwater management objectives required by the conditions of consent – outlined further through **Section 3** of this paper. Due to its depth and steep embankment configuration, the pond also had low visual and aesthetic values and posed a safety risk to the public and potential difficulties with maintenance and cleaning.

Figure 1: Location Plan

Due to the reasons outlined above, in 2010 NSCC undertook a comprehensive evaluation of the pond in its form at that time against the various relevant stormwater management objectives (i.e. those required by the associated resource consents, as well as current best practice objectives), as well as the scoping of redevelopment options to improve its stormwater management performance and amenity values.

3 ORIGINAL POND AND CATCHMENT CHARACTERISTICS

3.1 EXISTING CATCHMENT DESCRIPTION

The existing contributing catchment to the Carol Lee pond is entirely comprised of fully-developed residential land uses, and includes portions of Carol Lee Place, Hatfield Place, Quail Drive and Gills Road. The pond is within the 'Wayside Stream catchment' and it discharges to an unnamed watercourse which ultimately leads to the Lucas Creek and the upper Waitemata Harbour. Auckland Council are seeking to maintain the Wayside Stream as one of the best urban streams in the city so that it continues to form a green corridor through the catchment, providing for excellent amenity, ecological value, ease of movement and safe stormwater conveyance (Auckland Council, 2012).

The following parameters were used within a TP108 analysis to determine the required water quality and extended detention volumes, as well as pre and post development 2, 10 and 100 year ARI storm event peak flow rates from the catchment (based on TP10 and TP108 methodologies):

- Total catchment area :- 2.97 ha (of which about 60% is impervious)
- Catchment length :- 0.26 km
- Catchment slope (Sc) :- 0.104
- Time of concentration (Tc) :- 10 minutes

Table 1 below summarises the results from the TP108 analysis of the catchment (disregarding any benefits of the existing pond function).

Table 1: Existing Catchment Analysis

WQ Volume (50% credit)	ED Volume	2 Year ARI Peak Flow (m^3/s)		10 Year ARI Peak Flow (m^3/s)		100 Year ARI Peak Flow (m^3/s)	
		Pre	Post Uncontrolled	Pre	Post Uncontrolled	Pre	Post Uncontrolled
482 m^3 (241 m^3)	620 m^3	0.207	0.328	0.443	0.586	0.767	0.932

3.2 ORIGINAL POND DESIGN OBJECTIVES

Due to the timing of the development, the initial objectives for the stormwater management system at Carol Lee Place as required by the conditions of consent were originally aligned with ARC's (now superseded) earlier version of TP10 (1999), being summarised as follows:

- Permanent water storage volume of 120m^3 and wetland plants to provide water quality treatment;
- Extended detention to mitigate channel erosion, by storing the 30mm event and releasing over 24 hours;
- Maintaining pre-development 2, 10 and (if possible) 100 year ARI storm event peak flow rates.

It is noted that the options evaluation undertaken in 2010 (and described in **Section 4** of this paper) was based on the more recent 2003 version of TP10. This latest standard imposes more rigorous controls when compared to the earlier 1992 and 1999 versions, resulting in a comparatively superior outcome.

3.3 ORIGINAL POND PERFORMANCE ANALYSIS

The water quantity performance of the original pond was modelled using HEC-HMS software, and its efficiency and capacity were assessed against TP10 (2003) criteria. The various parameters for the original pond at Carol Lee Place were derived from as-built drawings and were confirmed during on-site investigations. These parameters are summarised as follows:

- Length to width ratio :- 1:1
- Side slopes :- 2:1
- Bench above permanent water level :- No
- Forebay :- No
- Top of Bank (ToB) surface area :- ~320 m^2

- Pond floor surface area :- ~70 m^2
- Total pond depth (floor to ToB) :- 3m
- Slow release outlet :- 150mm diameter at pond floor level
- Primary outlet :- 100mm slot in riser, 1.0m from the base
- Secondary outlet :- 550mm scruffy dome, 1.9m from base
- Emergency spillway :- 2.8m long broad crested spillway

The original pond did not maintain a permanent water level due to the fact that the lowest outlet orifice was located at the pond floor level (refer to **Figure 2**), leaving no allowance for sedimentation build-up and thus introducing a long term risk of blockage. This effectively meant that the device was not providing a sedimentation function or any other form of water quality treatment. **Figure 2** below shows the configuration of the original pond and outlet system.

Figure 2: General View of Original Pond Looking South West with Close-up of Outlet

The summary presented in **Table 2** (refer to **Section 4.1.6** of this paper) indicates that the original pond largely mitigated peak flows for the 2 year ARI event to pre-development levels; however the 10 and 100 year pre-development rates were not maintained. Extended detention was not provided in view of the 150mm orifice being grossly oversized for this purpose, while in addition (and as already mentioned) the pond did not provide any effective stormwater quality treatment.

Furthermore, the primary piped outlet from the original pond discharged directly into an open channel within a fenced and residential private property, and continued overland through three other properties prior to discharging to the Gills Road Reserve. Site investigations in late 2011 identified that as a result, the past outfall arrangement has created severe stream bank erosion and channelisation, as further discussed in **Section 5.1.2** of this paper. This situation was far from ideal, as the overland flow path is not fenced, and high flows along this flow path could have introduced a safety hazard.

4 OPTIONS ASSESSMENT FOR POND REHABILITATION

Due to the reasons outlined in **Section 3** of this paper, in 2010 NSCC undertook to consider redevelopment options for the Carol Lee pond in order to improve its stormwater management performance, as well as it, aesthetic and safety values. This section of the paper provides an overview of the options identification and analysis subsequently undertaken in 2010.

4.1 OPTIONS CONSIDERED

The five options examined for the redevelopment of the Carol Lee Pond are outlined below. Each option was assessed against the 2003 version of TP10 to determine the likely water quality performance, and with the use of HEC-HMS to estimate the functionality of the device in terms of its potential water quantity performance.

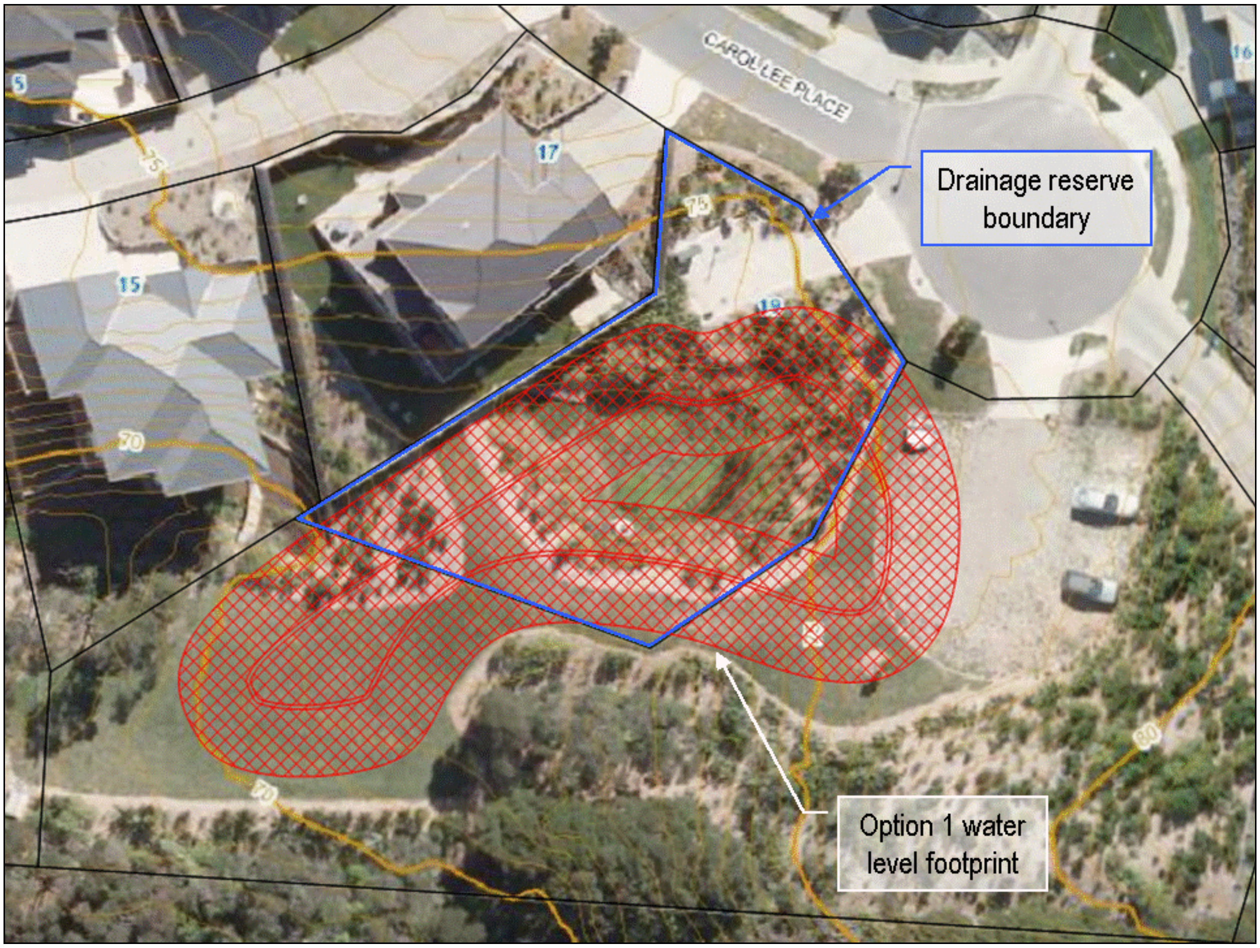
4.1.1 OPTION 1 - TECHNICALLY OPTIMUM POND

Option 1 entailed a 'technically' optimum scenario, assuming the device footprint could extend beyond the drainage reserve and onto recreational reserve land (refer **Figure 3**). This option consisted of a constructed pond designed in accordance with TP10 (2003), and included the following parameters:

- Length to width ratio :- 3:1
- Side slopes :- 3:1
- Bench above permanent water level :- Yes, 0.3m wide
- Top of Bank (ToB) surface area :- ~1060 m^2
- Pond floor surface area :- ~160 m^2
- Total pond depth (floor to ToB) :- 2.8 m

Due to the volume requirements coupled with the relatively gentle pond embankment slopes, length to width ratio and the provision of a safety bench, this option resulted in a an excessive footprint which was not practicable for the site due to topographical constraints, geotechnical concerns, the wider recreational requirements of the reserve, and the pressure to keep the redeveloped system within the boundary of the drainage reserve.

Figure 3: Concept Design Footprint for Option 1



As detailed above, this option represented an ideal scenario and was designed in accordance with TP10 (2003) to achieve full water quality treatment, extended detention, and pre-development 2 and 10 year peak flow rates (refer to **Section 4.1.6** of this paper for a tabulated performance summary of Option 1). Due to the form of a pond of this design, largely dictated by the large volume required for extended detention as well as the length to width ratio and shallow side slopes, the 100 year post-development peak flow rate was also attenuated to a large degree.

The ballpark rounded cost associated with this option was estimated at $270,000, excluding any land costs associated with works outside of the drainage reserve.

4.1.2 OPTION 2 – DETENTION ONLY POND

The second option was a stormwater pond designed largely in accordance with TP10, albeit with compromises on the provision of water quality treatment. The parameters which affect water quality performance of a stormwater pond (including permanent water storage and length to width ratios) were reduced, while extended detention and full 2 and 10 year peak flow attenuation were provided for as a priority. Due to the detention volume requirements, the pond footprint under this option also extended beyond the drainage reserve boundary (refer to **Figure 4**).

As with the 'technically' optimum solution (Option 1), the 100 year peak flow rate was also attenuated albeit to a lesser extent. It was also noted that the compromised water quality performance could be partially alleviated by introducing a bathymetric wetland design within the permanent water storage area of the pond. Such a design would increase the effective water quality volume by a factor of 1.5. The main design parameters for this option are:

- Length to width ratio :- 2:1
- Side slopes :- 2:1
- Bench above permanent water level :- No
- Top of Bank (ToB) surface area :- ~660 m^2
- Pond floor surface area :- ~130 m^2
- Total pond depth (floor to ToB) :- 3.6 m

Figure 4: Concept Design Footprint for Option 2

The performance of the Option 2 pond is summarised in **Table 2** – refer to **Section 4.1.6** of this paper.

If the drainage reserve boundary were not a significant obstacle, this option would be considered to be practicably and technically feasible, albeit with a compromise in terms of the stormwater quality objective.

The relative water quality treatment efficiency (in accordance with TP10 2003 table 3.1) for this option was estimated to be approximately 50%. With a wetland-base design within the permanent water level and a factored equivalent water quality volume of 112m^3, the relative efficiency for a wetland scenario would be approximately 60%.

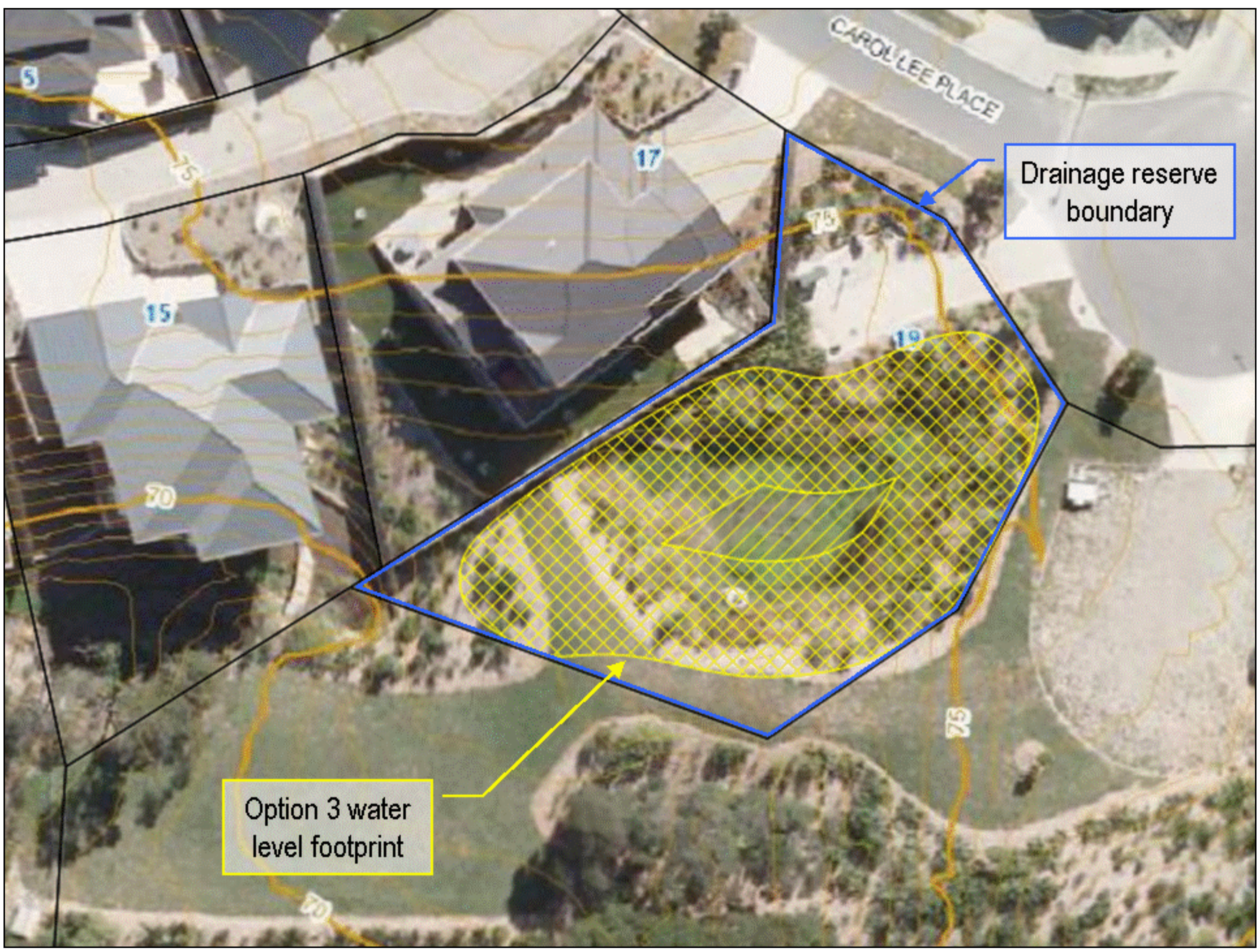
The ballpark rounded cost associated with this option was estimated at $230,000, excluding any land costs associated with works outside of the drainage reserve.

4.1.3 OPTION 3 – OPTIMISED POND WITHIN DRAINAGE RESERVE BOUNDARY

The third option considered was a rebuilt, optimised pond within the current boundary of the drainage reserve (refer to **Figure 5** below). The concept design of this option effectively constituted a scaled-down version of the optimum pond. All management objectives are therefore compromised by approximately 50%; however the parameters could have been further optimised and tailored to meet specific priorities while compromising on others. The adopted design parameters for this Option were as follows:

- Length to width ratio :- 1.5:1
- Side slopes :- 2:1
- Bench above permanent water level :- No
- Top of Bank (ToB) surface area :- ~500 m^2
- Pond floor surface area :- ~40 m^2
- Total pond depth (floor to ToB) :- 3.5 m

Figure 5: Concept Design Footprint for Option 3



The estimated performance of the Option 3 pond is summarised in **Table 2** (refer to **Section 4.1.6** of this paper), noting that the water quantity performance is based on an arrangement where all relative objectives are balanced (i.e. preference was not afforded to one outcome over another):

With the configuration modelled above, the relative water quality efficiency for this option would be approximately 60%. With a wetland base design as detailed in Option 2, the relative efficiency for Option 3 could also be increased. However, a pond or wetland in this location would not achieve an acceptable length to width ratio, again compromising treatment performance.

The ballpark rounded cost associated with this option was estimated at $200,000.

4.1.4 OPTION 4 – COMBINED RAINGARDEN AND UNDERGROUND DETENTION TANKS

The fourth option involved the development of a hybrid raingarden and underground tank system within the confines of the drainage reserve (refer to **Figure 6**). This option aimed to eliminate the need for a deep pond or wetland in this location in order to improve the aesthetic and safety values of a treatment system in this location. The functions of the raingarden (i.e. both water quality and quantity) would be complimented by a 'crate' type underground detention system to further achieve water quantity objectives. The concept effectively moved the main storage function of the device to below ground, largely removing long term safety risks normally associated with deep pond systems. Furthermore, the use of an underground crate system enabled more efficient use of space to achieve maximised storage volumes through near vertical excavation boundaries, compared with minimum 1(v) in 2(h) to 1(v) in 3(h) slopes required for a pond system.

The concept design for Option 4 adopted outcomes from recent research in relation to raingarden performance (Facility for Advancing Water Biofiltration, 2009). This research indicates that a permeability rate of between 100-300mm/hr (represented by 'k' values) is desirable for raingarden biofiltration media. This increased rate of permeability relative to current TP10 standards (which prescribes a 'k' value of 0.3m/day or 12.5mm/hr) is beneficial from a water quality perspective, as well as in terms of optimising the design and sizing of raingardens. A reduced raingarden depth (relative to TP10, 2003 guidelines) was also considered necessary in this instance to the physical restraints on site. This reduced media depth is also supported by recent research which indicates that most of the suspended particles captured by raingarden systems typically accumulate within the upper media horizon (100-200mm) (Facility for Advancing Water Biofiltration, 2009). As such a permeability rate of 100mm/hr and a raingarden depth of 600mm were used for the Option 4 concept design. It is reiterated that these values are not strictly in-line with TP10 (2003) but were considered to be appropriate under the circumstances of this retrofit scenario.

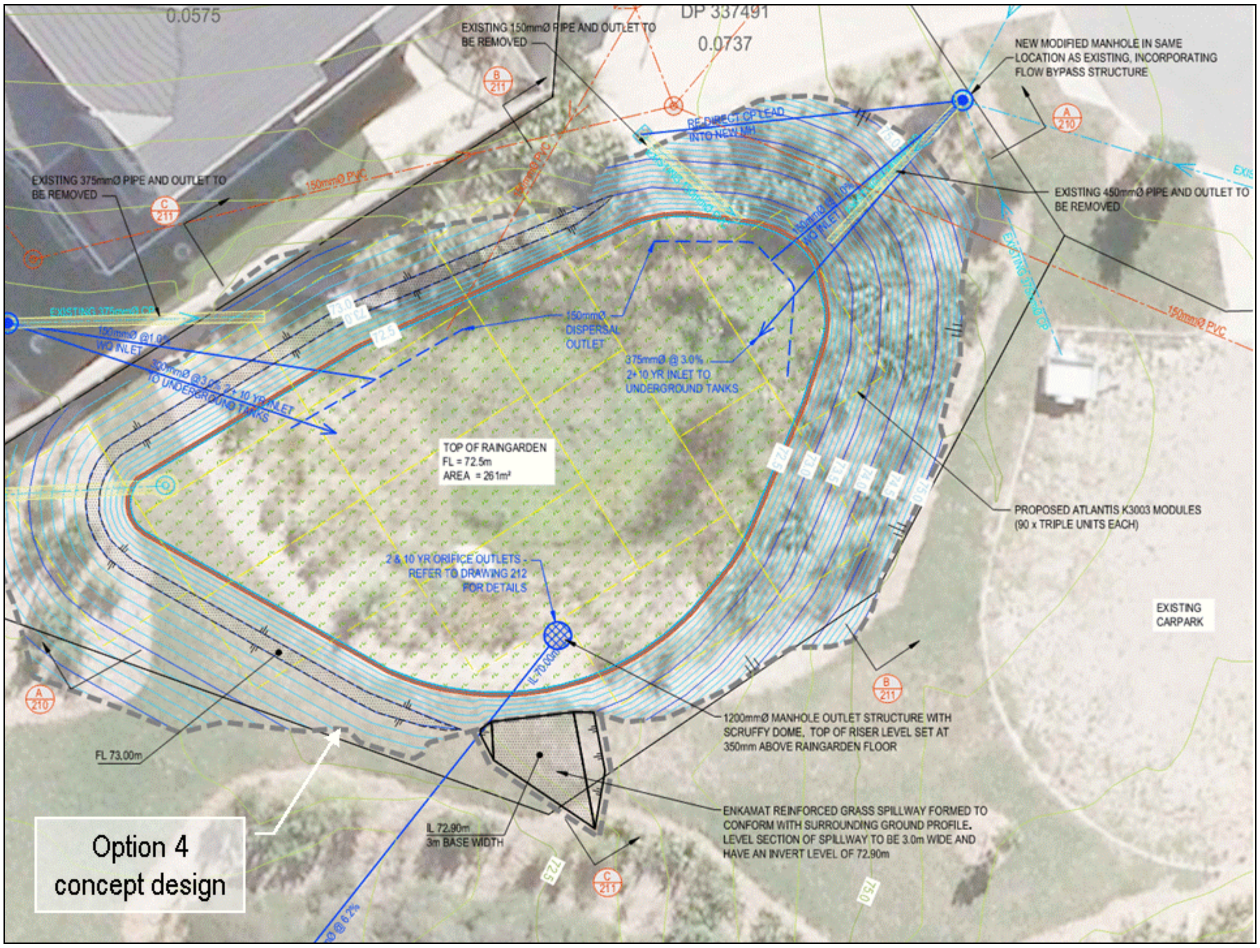
It was also recommended through the concept design of Option 4 to relocate the current outfall location to a point within the public reserve land south of the pond; thereby diverting overland flows away from private property (refer to **Figure 6**).

The adopted concept design parameters for the Option 4 concept are summarised as follows:

- Raingarden soil media depth :- 600mm
- Raingarden area :- 261 m^2
- Raingarden secondary outlet :- Scruffy Dome 350mm above raingarden floor

- Raingarden emergency spillway :- Reinforced grass 3.0m wide spillway with 4h:1 Side Slopes
- Atlantis tank area :- 352 m^2 (332 m2 net storage area)
- Atlantis tank depth :- 1310 mm
- Atlantis tank 2 year ARI Outlet :- 2 x 280mm OD PE80B SDR17 (242 ID)
- Atlantis tank 10 year ARI Outlet :- 2 x 280mm OD PE80B SDR17 (242 ID)

Figure 6: Concept Design for Option 4 - Combined Raingarden and Detention Tanks



The performance analysis results for Option 4 are summarised in **Table 3** (refer to **Section 4.1.6** of this paper).

With the concept configuration for Option 4, the relative water quality efficiency for this option would be approximately 75% when accounting for the proposed (and current best-practice) higher permeability media. When assessed against TP10 requirements (with a lower k value), a less overall treatment efficiency was obtained.

The configuration adopted for the concept design of Option 4 was unable to fully contain the runoff volume from the 34.5mm storm event due to the confined and limited extent of the drainage reserve, noting that the overall depth of the system was restricted by geotechnical limitations, primarily during the construction phase. This resulted in a compromise in terms of meeting the full extended detention objectives prescribed by TP10 (2003), which stipulates that the full 34.5mm storm volume must be provided for within the system and designed to be slowly released over a 24 hour period. However as indicated in **Table 3**, most of this runoff volume is able to be routed through the raingarden (as modelled through HEC-HMS) while achieving a slow release rate during the 34.5mm storm event. This is in line with the broader aquatic habitat and stream channel protection philosophies which are established in both TP10 and the Auckland Council Regional Plan (Air, Land and Water).

The concept design for Option 4 resulted in full attenuation of the 2 and 10 year ARI events to pre-development levels, and attenuation of the 100 year ARI event to within 5% of pre-development levels. As such, the performance of this device in terms of peak flow attenuation would comply with the requirements of the ARC resource consents and design guidelines.

The ballpark rounded cost associated with this option was estimated at $360,000.

4.1.5 OPTION 5 – STORMWATER POND WITH VERTICAL WALLS

The fifth option involved a detention pond system within the boundary of the drainage reserve, similar to Option 3, albeit with the maximisation of the potential pond volumes via the use of structural retaining walls around the pond boundary. With the use of near-vertical retaining structures, the achievable detention volumes within the drainage reserve would enable Option 5 to fully meet stormwater quantity objectives.

A concept design and assessment of this option was not undertaken, however the broad idea was included for comparative purposes. With the adoption of near vertical walls around the pond boundary (which rough calculations suggest would need to be greater than 3.5m and up to 6.5m high in order to achieve the extended detention and peak flow attenuation volumes) and by relaxing any design factors affected by safety considerations (including safety benches and permanent water depth), the potential storage within the pond could largely achieve the full suite of stormwater management objectives. A system designed within these parameters would however not be ideal in terms of water quality treatment due to the physical restrictions preventing an optimum length to width ratio. Such a system would also pose significant safety and maintenance issues due to the high water depth resulting from the dead and live storage volumes, and would have negative aesthetic impacts.

The costs associated with the retaining structures would be prohibitive, as reflected by the overall estimated ballpark cost for this option of $580,000.

Option 5 was not considered further due to the significant health and safety risks and negative aesthetic values associated with the high vertical drops and deep water depths.

4.1.6 PERFORMANCE SUMMARY OF OPTIONS

For comparative purposes, the performance summaries of the original pond and Options 1, 2 and 3 have been collated within **Table 2** below, while the performance of Option 4 is summarised in **Table 3**.

Table 2: Performance Summary of Original Pond and Options 1, 2 and 3

	WQ Volume	ED Volume as per	Pond	2 Year ARI Peak	10 Year ARI	100 Year ARI

	(Req'd = 75% TSS eff.) (m^3)		TP10 (m^3)		Volume (ToB)	Flow (m^3/s)		Peak Flow (m^3/s)		Peak Flow (m^3/s)	
Original Pond	Req'd	Actual	Req'd	Actual	656 m^3	Pre	Post	Pre	Post	Pre	Post
	241	0	620	0		0.207	0.229	0.443	0.568	0.767	0.905
Option 1	Req'd	Actual	Req'd	Actual	1600 m^3	Pre	Post	Pre	Post	Pre	Post
	241	242	620	622		0.207	0.149	0.443	0.438	0.767	0.814
Option 2	Req'd	Actual (x1.5)	Req'd	Actual	1350 m^3	Pre	Post	Pre	Post	Pre	Post
	241	75 (112)	620	622		0.207	0.144	0.443	0.442	0.767	0.866
Option 3	Req'd	Actual (x1.5)	Req'd	Actual	835 m^3	Pre	Post	Pre	Post	Pre	Post
	241	130	620	329		0.207	0.272	0.443	0.555	0.767	0.895

Table 3: Performance Summary of Option 4 – Hybrid Raingarden & Detention Tanks

Raingarden Area (m^2)		ED Volume Routed via RG (HEC-HMS) (m^3)		Total Vol. (RG + Tank)	2 Year ARI Peak Flow (m^3/s)		10 Year ARI Peak Flow (m^3/s)		100 Year ARI Peak Flow (m^3/s)	
TP10 media (modified media)	Actual	Req'd	Actual	~647 m^3	Pre	Post	Pre	Post	Pre	Post
1367 (259)	~261	620	~611		0.207	0.183	0.443	0.442	0.767	0.806

4.2 OPTIONS ANALYSIS

A detailed analysis of each of the identified options was undertaken in order to establish the preferred option based on a number of criteria and considerations. These included the main stormwater management objectives, being water quality, extended detention, and peak flow rate attenuation, as well as qualitative matters such as amenity values, safety issues, maintenance requirements and cost.

Figures 7, **8** and **9** below present graphed relationships of each of option against the stormwater management objectives for the device and the relative footprint associated with the particular pond redevelopment concept, while also relating these outcomes to cost estimates for each concept (the size of each 'bubble' in the graphs indicates the relative cost of each option). A full cost / benefit analysis was not undertaken for this options assessment due to the overarching limitations on each option, as discussed below.

Figure 7: Summary of Relative Water Quality Performance

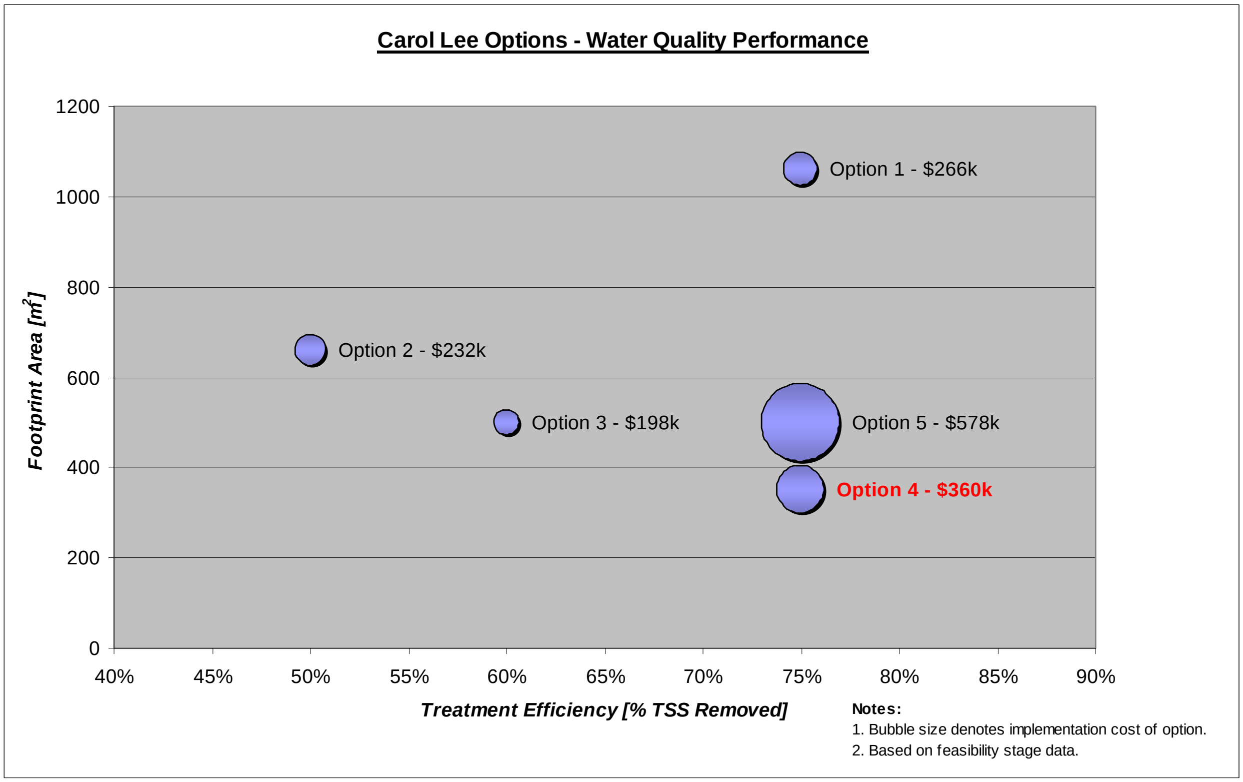


Figure 8: Summary of Relative Extended Detention Performance

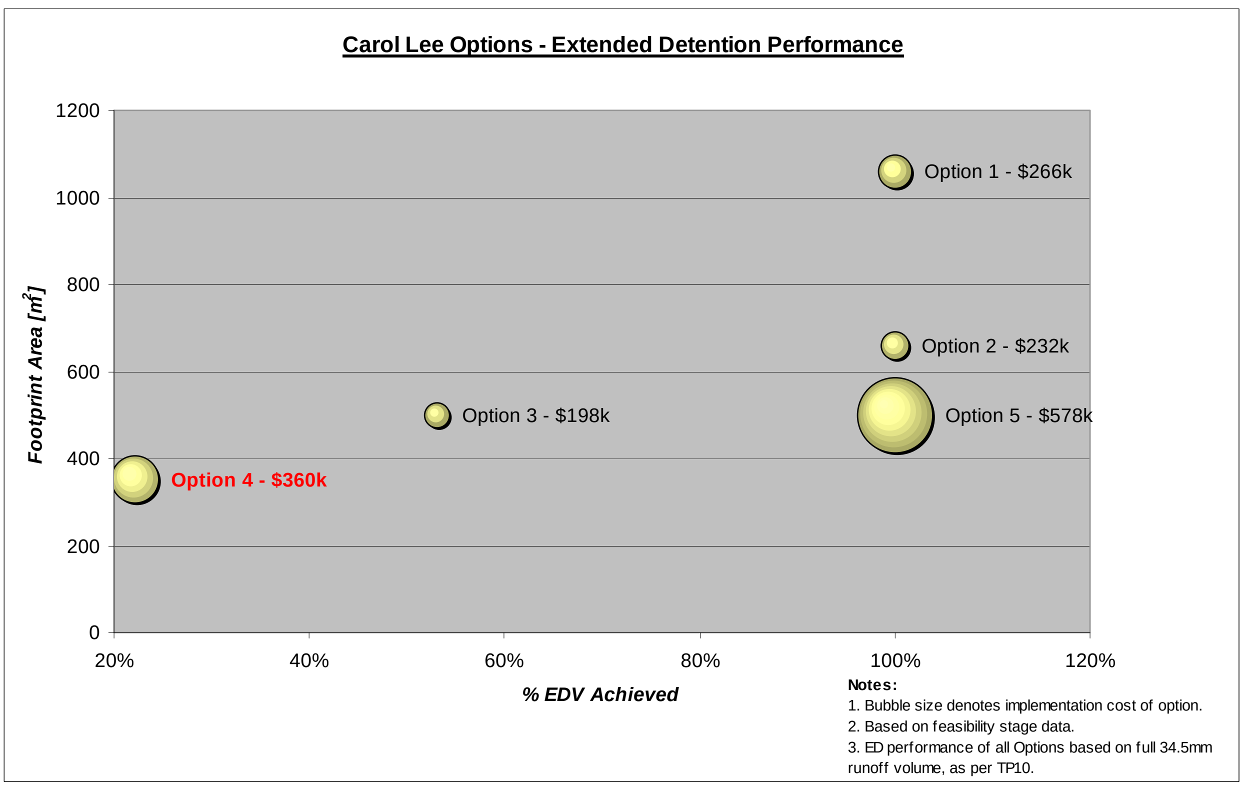
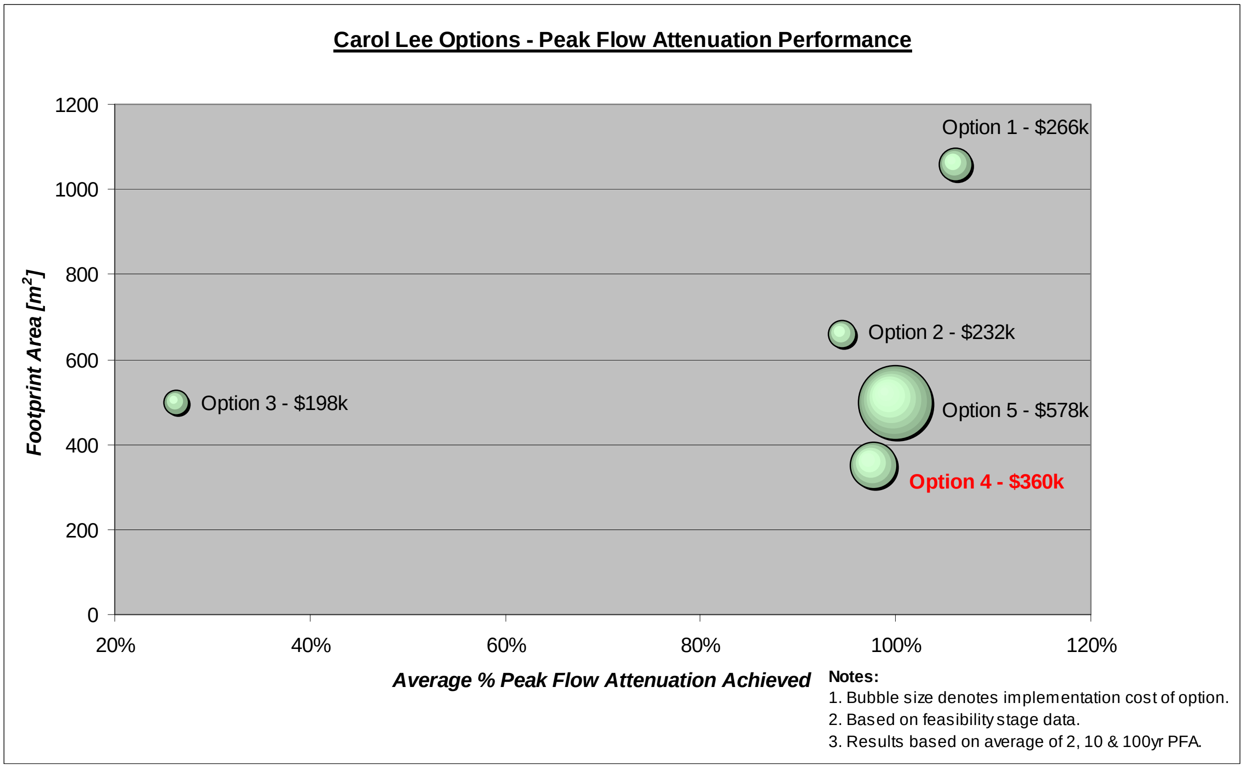


Figure 9: Summary of Relative Peak Flow Attenuation Performance



Option 1 represented the ideal option in terms of stormwater management outcomes; however it presented an obstacle in terms of safety and maintenance associated with a deep wet pond in an established residential area, as well as difficulties with the footprint extending across the recreational reserve. Due to these reasons (among others) this option was not considered to be viable and was therefore discarded from further analysis.

The Option 2 pond would not fully achieve stormwater quality treatment requirements but would meet extended detention and peak flow attenuation objectives. As with Option 1 however, Option 2 would result in a deep pond and a footprint that extends outside the drainage reserve area, resulting in the same drawbacks as Option 1 in this respect (albeit to a lesser degree). Option 2 was therefore discarded from further consideration.

Option 3 would have entailed the most economical solution and a pond which was fully contained within the drainage reserve boundary; however the restricted available area means that stormwater performance would be heavily compromised, together with similar safety concerns as those associated with Options 1 and 2.

In view of the poor performance that could have been realistically achieved by a wet pond system in such a confined area (as considered under Option 3), the relatively large area serviced and the detrimental visual, amenity, safety and maintenance aspects associated with such systems, Option 4 (involving the construction of a raingarden complimented by underground detention devices) was identified as a viable alternative. While Option 4 had the second highest cost of the five options (excluding land costs associated with Options 1 and 2), Option 4 would result in a facility with a comparatively higher amenity value and superior stormwater management performance.

Furthermore, it is widely accepted that raingarden devices are inherently superior to wet ponds from a stormwater quality view point, and also offer extended detention benefits due to the slow release rate achieved via percolation through the soil media. When coupled with the underground detention tanks (designed to address water quantity objectives), it was therefore considered that Option 4 represented the best use of space and would result overall in the most desirable stormwater management facility. It was therefore concluded that Option 4 constituted the best practicable option for the redevelopment of the Carol Lee Place pond.

4.3 SUMMARY OF OPTIONS ANALYSIS

As a result of the detailed options analysis undertaken in 2010, Option 4, the hybrid raingarden and detention tank system was identified as the best practicable option for the rehabilitation of the Caro Lee Place pond. The system could be designed to be in-line with current best practice standards for raingarden systems, with increased permeability and reduced media depths to provide a device that could achieve 75% TSS removal. Through the provision of an underground detention cell network, the device could also be designed to achieve water quantity objectives to the greatest practicable degree, while remaining within the footprint of the drainage reserve. In order to achieve 2 and 10 year ARI storm event peak flow attenuation to pre-development levels, a compromise was necessary with regard to the 34.5mm extended detention methodology as prescribed by TP10 (2003). Despite this compromise as well as the comparatively higher cost, when coupled with the enhanced amenity values and safety risks associated with this concept, Option 4 was identified as the preferred option, and was accepted by the former ARC as the BPO for the purposes of the associated resource consents (varied by way of Section 127 of the RMA).

5 HYBRID RAINGARDEN AND DETENTION TANK SYSTEM

5.1 OVERVIEW

The proposed device involves the construction of a hybrid stormwater attenuation and treatment device, in the form of an underground modular cell detention tank (comprised of Atlantis modular crate detention systems), overlain by a raingarden system, constructed directly above the underground tank system. An overview of the detailed design phase for the device (undertaken in late 2011 and early 2012) is provided in **Section 5.2** of this paper.

5.1.1 OVERARCHING OBJECTIVES

Current stormwater management objectives for the Auckland region are determined by a number of contributing documents, including the RMA, National Policy Statements, Regional Policy Statements, Regional Plans, District Plans and non-statutory guidelines such as TP10. Both the RMA and the Regional Plan (Air, Land and Water) provide for the assessment and authorisation of discharges (including stormwater discharges) when they are demonstrated to be the best practicable option (BPO) for the specific circumstances. This is an important concept with respect to the Carol Lee Pond, as it has been demonstrated that due largely to the physical constraints of the site and retrofit scenario for the works, it is not practicable to retrofit the full and ideal stormwater management objectives for such a development. In this context therefore, the proposed hybrid management system is arguably the BPO for the catchment.

The current 2003 version of TP10 establishes the following overarching primary stormwater management objectives (noting that these are more rigorous than those prescribed through the earlier versions):

- *Stormwater quality treatment* for the removal of 75% total suspended solids on an average long-term basis;

- *Extended Detention* for the control of stream channel erosion from more frequent flows and larger runoff volumes, by storing the runoff from the first 34.5mm (in contrast to 25-30mm as per the prior versions of TP10) of rainfall and releasing it over 24 hours;
- *Peak Flow Attenuation* to pre-development levels for the control of stream bank full erosion (by attenuating the 2 year ARI event) and for flood mitigation (by attenuating the 10 and 100 year ARI events);
- *Scour protection* for the mitigation against potential scour and erosion arising from concentrated point stormwater discharges.

Furthermore, in view of the location of this device within an established residential area, NSCC's (now Auckland Council's) objectives for this project included not only the provision of a functional and efficient stormwater system, but also a facility that is aesthetically pleasing, safe and well received by the local community.

5.1.2 REVISED DESIGN OBJECTIVES

The concept design for the hybrid device provided for full water quality treatment (i.e. to a 75% TSS removal standard based on current best practice parameters for the raingarden media) and full 2 and 10 year ARI storm event peak flow attenuation to pre-development levels, as well as partial extended detention (using the HEC-HMS routing method) and 100 year ARI storm peak flow attenuation.

Further site investigations subsequent to the concept design phase, revealed significant levels of erosion within the downstream receiving environment (refer to **Figure 10** – the images highlight the attempts made by Auckland Council Stormwater Operations to provide temporary remediation of the erosion through polythene lining). This is likely to be attributable to the largely unmitigated discharge of small and frequent storm event flows from the Carol Lee pond. As such, rather than shifting the outfall location to an existing depression to the south of the reserve as originally conceived – potentially introducing an additional erosion risk, it was instead resolved to provide for extended detention of small storm event flows to the greatest practicable degree and to maintain the existing discharge route. The discovery of these erosion issues also led to the inclusion of restoration works for the downstream affected sections of stream into Auckland Council's projects programme, with the stream restoration works projected for construction as a separate project during the 2012-13 earthworks season.

The theoretical 34.5mm storm event extended detention volume relative to the pond's contributing catchment is approximately 620m^3 (refer to **Tables 1**, **2** and **3** above). The concept design for the hybrid device did not provide a significant volume dedicated to extended detention – instead focussing on providing for full 2 and 10 year ARI storm event peak flow attenuation, and adopting a HEC-HMS modelling approach to address extended detention. The modelling approach to extended detention relies on the 34.5mm storm being 'routed' through the management device using HEC-HMS, thereby accounting for outflows from the system throughout the storm event. These outflows result in a significantly reduced storage volume requirement when compared with the more conservative approach prescribed by TP10 (2003), whereby the full 34.5mm storm volume must be provided for within the system (i.e. not accounting for outflows). However, through the detailed design stage for the hybrid system in light of the discovery of severe downstream erosion, the device has now been designed to provide for extended detention in accordance with TP10 to the greatest practicable extent (specifically, within the drainage reserve boundary and to the maximum depth achievable under the geotechnical limitations). The detailed design results in approximately 490m^3 of storage volume being provided for within the system, and with the extended detention outlet orifice being sized to release this volume over a 24 hour period (through a 65mm orifice).

The revised detailed design achieves a greater balance between the modelling approach to extended detention and the more conservative methodology as prescribed by TP10.

Figure 10: Photos taken during site visit on 9 Sep. 2011, illustrating severe downstream erosion

As a result of the shift in approach relative to the water quantity performance of the device, the remaining volume within the device that is available to attenuate larger storm event peak flows is reduced. This is due to the geotechnical and areal limitations on the overall storage volume achievable and available. As such, the detailed design for the device is no longer capable of providing full peak flow attenuation to pre-development levels. The device, however, is able to attenuate peak flows to a greater extent than the existing pond arrangement – being significantly less than the post-development peak flows.

5.1.3 RISKS AND CONSTRAINTS

The Carol Lee Pond rehabilitation project presented several risks and constraints, the most notable of which are:

- The stormwater infrastructure discharging at the northern part of the device is deep, thereby requiring deep excavations to accommodate the proposed underground detention device.
- Steep topography including deeply incised pond embankments result in steep (and deep) excavations and careful construction management controls.

- Close proximity of dwellings and well established residential areas to proposed inlet and outlet pipes, requiring the construction of stormwater pipes by way of trenchless technology in close proximity to buildings.
- Severe stream channel erosion directly downstream of the existing pond discharge point, with associated risks to overall land stability in close proximity to residential dwellings.
- Proposed underground tank – raingarden combined system has not been tried before introducing a risk of “unproven” technologies.

These risks and constraints were addressed through the detailed design phase of the project.

5.1.4 RESOURCE CONSENT REQUIREMENTS

The original pond design was subject to a number of resource consents issued by the former Auckland Regional and North Shore City Councils (including stormwater discharge, earthworks, land use and subdivision consents). The proposed pond redevelopment has been permitted through successful variations to these consents where relevant, and to a new land use consent to enable the reconstruction works.

5.2 DETAILED DESIGN

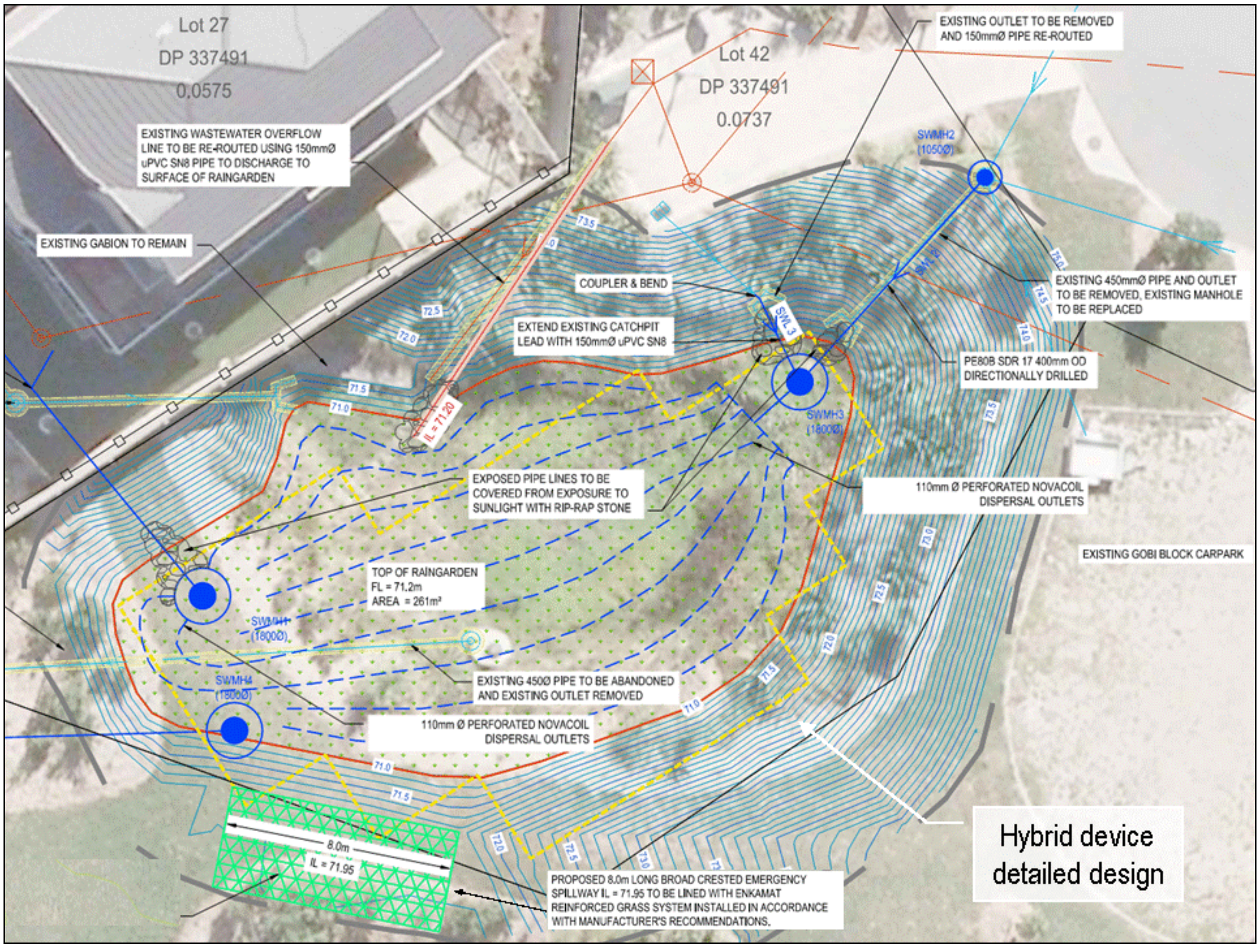
5.2.1 GENERAL

The detailed design of the hybrid device did not alter dramatically from the concept design and further developed the main features of the system, refer to **Figure 11**. Stormwater runoff from the contributing pipe network will be directed to the raingarden in the first instance, whereby runoff from first flush flows will be diverted to the raingarden surface through a dispersal pipe inlet system. Flows through the raingarden will drain vertically and discharge directly into the subsurface Atlantis tank system.

Flows in excess of the first flush will be diverted away from the raingarden by way of specifically designed inlet structures and made to discharge directly to the underground tank. Extended detention and peak flow attenuation has been provided for within the underground tank system, with the flows being regulated by a 1800mm diameter outlet manhole structure.

The hybrid raingarden-tank system will discharge to the same downstream environment which currently receives flows from the existing pond outlet. The proposed outlet will incorporate a 1200mm diameter *US Army Corps of Engineers* style stilling well as provided for by TP10 (U.S. Department of Transportation (2006)).

Figure 11: Detailed Design Plan of Hybrid Device



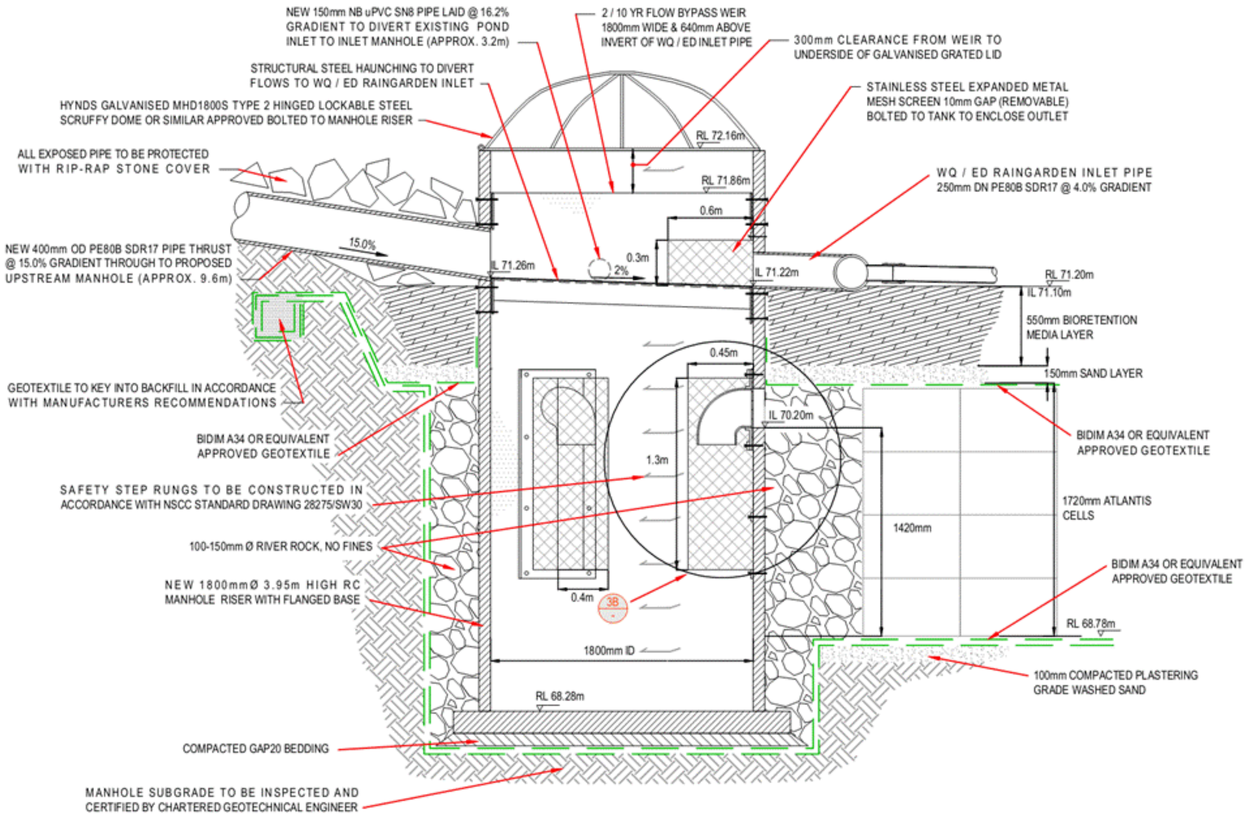
5.2.2 GEOTECHNICAL CONSIDERATIONS

The proposal involves deep excavations within the existing pond footprint in order to accommodate the underground Atlantis tanks and overlying raingarden. A geotechnical report was undertaken which addresses land stability, construction management, groundwater levels, drainage, flotation, sedimentation, and downstream erosion considerations, among other issues. This assessment proposed specific design considerations that have been incorporated within the detailed design of the device.

5.2.3 DESIGN INLET CONSIDERATION

Runoff is directed through the piped network into the device through two manholes, referred to as SWMH1 and SWMH3 (refer to **Figure 12**). These manholes are each to be constructed with an internal diversion weir to direct all flows of up to the 34.5mm storm event (extended detention – 'E.D.') to the raingarden through the dispersal inlet lines. The internal diversion structure and all associated components are to be Hot-Dip Galvanised after fabrication. During a storm event in excess of the E.D. capacity the internal weir is overtopped and stormwater flows are directed straight into the underground detention tanks. Water within the detention tanks is discharged through a single manhole riser outlet, with the flow rate controlled through four orifices (designed to pass the 2 and 10 year storm events). Once the capacity of these outlet orifices are exceeded or in the event of blockage, flows are able to build up within the outlet manhole and overflow through the grated lid into the raingarden.

Figure 12: Inlet Design Detail (Manhole SWMH3)



As both the inlet and outlet manholes are to be constructed within the underground tanks, 100-150mm Ø river rock backfill is to be used between the tank modules and the manhole to prevent movement of the modules. In order to prevent fouling (and blockage) of the dispersal lines and Atlantis modules, a series of 10mm gap bulk debris screens are to be installed within SWMH1, SWMH2 and SWMH3 to retain debris within the risers. These debris screens are to be bolted to the riser walls to allow for removal for inspection and maintenance. For the 2 and 10 year outlets, within the debris screens are 90° PVC pipe bends mounted with stub flanges and bolted to the riser walls. These bends are to be orientated downwards so as to prevent any floatables small enough to pass through the debris screen from entering the system.

The extended detention and water quality dispersal lines have been specified as 110mm diameter Novaflo perforated pipes, laid along the length of the raingarden and evenly spaced so as to provide an even spread of flows into the raingarden media.

5.2.4 RAINGARDEN SPECIFICATIONS

In order to provide adequate infiltration rates through the raingarden into the subgrade tank, as discussed in **Section 4.1.4** of this paper, a high-permeability biofiltration media is proposed. The higher infiltration rates will assist in enabling the smaller raingarden footprint. To allow for a reduced area of excavation due to limited space available on site, the excavation depth is to be reduced by incorporating a 550mm thick layer of biofiltration media in contrast to the TP10 requirement of 1.0m. These factors, although not strictly in accordance with TP10, are considered to have combined to form the BPO in this instance due to the restrictions associated with this retrofit scenario. It is noted that the non-TP10 factors of the design are supported by recent research in this field (Facility for Advancing Water Biofiltration, 2009).

Raingarden and embankment planting is to be undertaken in compliance with TP10 recommendations. In light of the alternative biofiltration media to be used special consideration is to be given to vegetation suited to well-drained soils.

5.2.5 ATLANTIS FLO-TANK SPECIFICATIONS

To prevent the raingarden filtration media and sediment from migrating into and clogging the Atlantis modules, the tank is to be lined on top with a single layer of geotextile cloth, Bidim A34 or equivalent, securely keyed into the embankment. In recognition of past experience in relation to use of geotextiles within raingarden systems, (where it has been found that there is a tendency for the Geotextile to become clogged in time), the design allowed for the geotextile to be overlaid with a 150mm transition layer of washed sand which would filter any fine sediment thereby mitigating against this risk.

The arrangement of the crate modules has been determined with consideration to excavation for construction with side slopes at a maximum of 1:1 and for practical construction of the tank, taking into account wrapping of the system in geotextile. The void between the temporary excavation and the tanks will be generally filled with 20/7 scoria (for the filling of larger gaps). SAP7 backfill will be used for filling of smaller voids.

The modules are to be constructed four crates high, with allowance for relevant reinforcing for the lower crates due to increased lateral earth pressures. In light of the expected lateral earth loading, the bottom crate is to be constructed with 5 cross-plates, with 3 cross-plates sufficient for the higher 3 crates.

It is recognised that the modular cell construction of the Atlantis subgrade detention system is inherently difficult to clear should significant levels of sediment accumulate within the system. As such, isolating the tanks from the surrounding soil is essential for successful long term operation of the device. The sides and bottom of the tank are to be therefore wrapped with a double lined geotextile cloth so as to prevent any migration of solids into the system. Wrapping of the tank is to be completed with all seams and folds secured to ensure no soils enter the system. The tank lining will allow for passage of groundwater into the system, preventing excessive hydrostatic pressures building up when the tank is empty thereby mitigating against any risk of tank flotation.

The tank is to be constructed on a 100mm thick layer of compacted plastering grade washed sand. The sand layer is to provide a smooth level surface on which to construct the tank system and to contain a 65mm slotted coil drainage network to remove any surplus groundwater and drain it to the outlet riser.

5.2.6 OUTLET CONFIGURATION

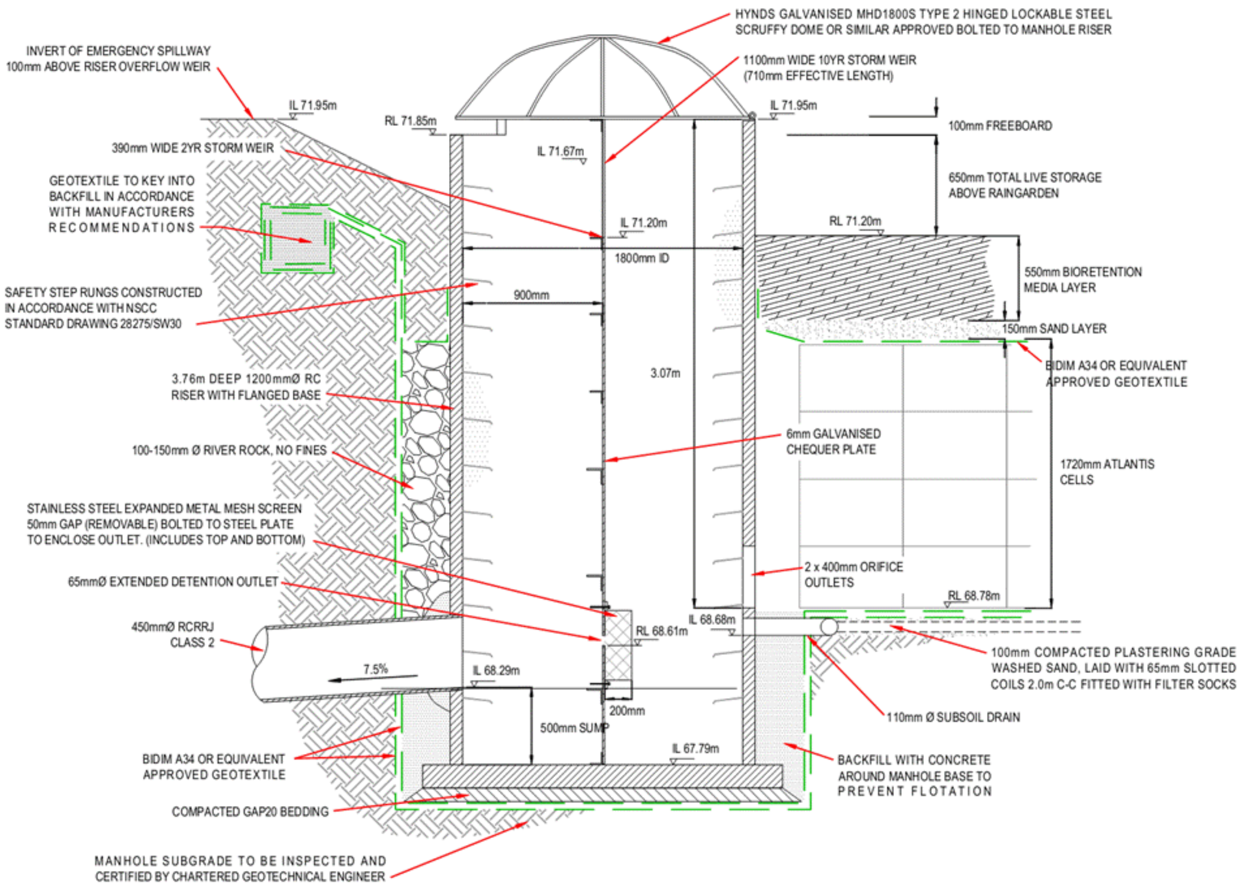
In light of the significant erosion observed downstream of the existing device, the proposed design for the rehabilitated device incorporates an ‘extended detention’ function as the primary water quantity design principle. By providing for extended detention to the greatest practicable degree, the overall design for the device results in reduced attenuation levels for peak flow rates during the 2yr and 10yr storms over that which was originally provided for through the concept design for the device. There is still a degree of improvement in peak flow attenuation when compared with the existing pond configuration.

The outlet manhole from the device, SWMH4, is to be fitted with a flow control weir inside the riser, bolted to the riser walls (refer to **Figure 13** below). The weir plate incorporates a 65mm diameter outlet orifice to control the slow release of the extended detention volume.

The device outfall stilling well, SWMH5, has been designed in accordance with the *US Army Corps of Engineers* guidelines. The stream channel in the vicinity and downstream of the manhole is to be adequately protected against erosion (as mentioned in Section 5.1.2), with these works being proposed as a separate project to be undertaken in the 2012-13 earthworks construction season.

The emergency spillway for the 100yr storm event is to be reinforced with Maccaferri Enkamat 18 erosion reinforcement to ensure degradation of the spillway does not occur through use over time. The reinforcement is to be placed 8m wide over the length of the spillway and total 6.5m length minimum over the embankment – in line with the manufacturer's guidelines.

Figure 13: Outlet Design Detail (Manhole SWMH4)



5.2.7 OPERATION AND MAINTENANCE

A draft operation and maintenance plan (OMP) has been developed for the system, addressing the raingarden, subgrade tanks, manholes and associated components within the hybrid device.

It is noted that a wastewater pump station is located adjacent to the device, and the emergency overflow from this station will discharge to the raingarden surface. Although likely to be a very rare occurrence, in the event of such an overflow, maintenance (potentially including partial replacement) of the raingarden filtration media will likely be needed so as to eliminate any health and safety risks.

6 WHERE TO FROM HERE?

6.1 TENDER

At the time of writing this paper, the hybrid raingarden and detention tank device has been tendered for construction, with a successful tender yet to be determined.

6.2 CONSTRUCTION

Auckland Council has funding in place to proceed with the redevelopment works upon appointment of a successful tenderer, with works anticipated to be completed by the end of May 2012.

6.3 POST-CONSTRUCTION MONITORING

Auckland Council plans to develop the draft operation and maintenance plan further, and implement a post-construction monitoring programme in order to monitor the on-going operation of the hybrid system. Important features include the geotextile membrane between the raingarden media and underlying detention tanks, as well as the on-going permeability of the biofiltration media. The operation of the water quality and extended detention flow dispersal system will also be monitored.

6.4 WIDER APPLICATIONS

The hybrid device conceived for the redevelopment of the Carol Lee Place pond is a purpose-designed solution to a particular problem, and is understood to be the first of its kind in the Auckland region. The design adopts a number of advanced techniques to achieve current best practice stormwater management objectives, particularly in relation to the raingarden portion of the device. The permeability rate of the biofiltration media is an important specification to ensure the success of the overall system. It is envisaged that the system can be used as a model for further similar applications around the region, and as a potential alternative to stormwater ponds. In this regard, there are a number of advantages to the hybrid raingarden and detention tank system over traditional wet ponds, which include:

- The raingarden media and intrinsic treatment systems provides a higher level of water quality performance relative to the sedimentation-only processes of a traditional wet pond;
- The device does not incorporate or rely on a permanent body of water to provide for water quality treatment, and thereby does not introduce a thermal issue (with associated potential adverse impacts on downstream ecology) as with traditional pond systems;
- The lack of a permanent body of water largely negates the aquatic weed problems associated with traditional ponds;
- The device can provide a better use of space, with the raingarden layer providing opportunities for amenity functions, e.g. park seats and walkways; and,
- The lack of a permanent body of water also largely negates the safety issues normally associated with wet pond systems.

7 CONCLUSIONS

The Carol Lee Place pond in Albany Heights, Auckland, built in 2004, was significantly undersized and insufficient to achieve the intended stormwater management objectives – being, water quality treatment to a 75% TSS removal standard, extended detention of the 34.5mm storm event, and 2, 10 and 100 year ARI storm event peak flow attenuation. As a result, the undersized pond was causing significant downstream channel erosion.

The options assessment undertaken by the former North Shore City Council identified a unique solution in the form of hybrid raingarden and detention tank system as the best practicable option for redeveloping the pond into a device that could better achieve the necessary objectives. Among numerous other benefits, the underground crate system enabled more efficient use of space to achieve maximised storage volumes through near vertical excavation boundaries. Furthermore, the hybrid design will be contained within the confines of the drainage reserve thereby maintaining the recreational functions of the neighbouring parks reserve, while the device presents opportunities for improved amenity values and reduced safety risks relative to the original pond system.

The detailed design process for the hybrid raingarden and detention tank system has resulted in a system that will provide extended detention to the greatest practicable degree as the main priority – almost fully detaining the 34.5mm runoff volume and slowly releasing this volume over a 24 hour period. The raingarden system will provide full water quality treatment to a 75% TSS removal standard, based on the specified 100mm/hr rate of hydraulic conductivity – in line with recent research outcomes. Furthermore, the device will provide peak flow rate attenuation for the 2, 10 and 100 year ARI storm events to levels below those that the pond system achieved.

The hybrid device is soon to be constructed (at the time of writing this paper) and will be closely monitored for operational success. It is anticipated that the system will have wide-reaching implications and could be replicated in similar situations throughout the Auckland region and beyond.

ACKNOWLEDGEMENTS

The work presented in this paper was funded by Auckland Council. Views expressed in this paper are those of the authors and do not necessarily represent policy or the position of the Auckland Council.

Barry Carter from Auckland Council provided an overview role of the Carol Lee Place pond redevelopment project from conception. Colleen Brent from Auckland Council managed the options assessment process and initial development of the hybrid system. Nick Vigar from Auckland Council undertook a technical review of the system on behalf of Council. Greg Edwards, Allen Jia and Jack Turner from AR Civil Consulting Ltd all contributed to the development and design of the hybrid system.

REFERENCES

Auckland Council (2012), 'Draft – Wayside Stream Catchment Management Plan.'

Auckland Regional Council (1999), 'Guidelines for Stormwater Runoff Modelling', TP108.

Auckland Regional Council (1999), 'Stormwater Treatment Devices - Design Guideline Manual', TP10.

Auckland Regional Council (2003), 'Design Guideline Manual - Stormwater Treatment Devices for the Auckland Region', TP10.

Facility for Advancing Water Biofiltration (June 2009), 'Guidelines for Filter Media in Biofiltration Systems', Version 3.01.

U.S. Department of Transportation (2006), 'Hydraulic Design of Energy Dissipators for Culverts and Channels', HEC 14, 3rd Edition.