AT-SOURCE WATER SENSITIVE URBAN DESIGN FOR RESIDENTIAL DEVELOPMENT: DESIGN TO CONSTRUCTION

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ABSTRACT

An application of water sensitive urban design that brings together the collaborative resources of a design team that is focused on delivering a practical solution to stormwater management. A 14ha residential development has been designed to utilise raingardens that have been specifically designed to treat runoff using enhanced onsite peat materials. This at source application also has the benefit of controlling the larger rainfall events without detrimental effects to the built environment which is located in the upper portion of a shallow gradient catchment, which is characteristic of Takanini, Auckland.

The development has recently been completed and the design team was involved closely during the construction phase. As with all good design the construction component is integral to achieving the best practical application of at-source water sensitive urban design.

KEYWORDS

Water sensitive urban design, low impact, stormwater management, design, construction

1 INTRODUCTION

A South Auckland residential subdivision, The Avenues at Addison, has adopted close-to-source stormwater management, with a “local sub-catchment management” (LSM) design approach. After several options (for stormwater management) were investigated the LSM was adopted as the best practical application. The design criteria were developed in close liaison with the local authority which addressed concerns about long term viability, operation and maintenance requirements as well as flood management. Ground water recharge is necessary at this site, as with surrounding areas to maintain ground water levels in the peat sub soil.

The design process included input from a variety of experts in scientific, construction and financial aspects of residential development. This collaborative approach ensured that the details of the relatively new approach to stormwater management were robust enough to take account of a range of design and operation requirements.

Once the design and approval stage was completed construction of the stormwater and other infrastructure began on site. Careful supervision and construction practices were put in place to ensure that all parties understood the design and requirements of the LSM devices, such as raingardens, swales and recharge pits.

2 BACKGROUND OF PROJECT

2.1 LOCATION AND HISTORY OF THE PROJECT

The site is located in Takanini, South Auckland, approximately 30kms south of the CBD. This area has been identified in the Auckland Region Growth Strategy for inclusion of medium density residential development. The Avenues is part of the Addison Development of a total of 80ha of residential subdivision undertaken by McConnell Properties Ltd. The Master plan includes a retail and community zone as well as a Retirement Village.

The Addison development is being undertaken in stages of which the Avenues is the fourth. The first three stages are completed with construction starting in 2000 (for stage 1) and first residence established by the end of 2002 including the formation of a residents association. This residents association completed the vision of McConnell Properties to have a community approach to the whole development. The housing construction within the 3rd Stage is currently underway with approximately one third completed at the time of writing. The Avenues first stage has been completed with 224c issued and the second and final stage imminent at the time of writing.

Liaison with the local authority , being Papakura District Council (PDC) over the full duration of the project ensured that the design could accommodate the needs of the end users and owners of the infrastructure. Operation and maintenance of the devices and pipe network will ultimately be PDC, or the larger entity to be formed in the latter part of 2010.

2.2 SITE CHARACTERISTICS

The Avenues development is approximately 14 hectares. The subsurface conditions are predominantly peat based with a high ground water table. The winter ground water table is between 0.5m to 1.0m below the ground surface and the average summer level is 1.5m below the ground surface.

The site has a very flat slope, which falls toward the catchment outlet in a westerly direction at an average grade of approximately 0.2%. This gradient allows the site to be developed, with respect to earthworks, with relative ease when working down-slope, e.g. from east to west, however when working across the slope (parallel with the contours) in a north-south direction, the proposed gradients require careful engineering of road and finished ground levels to achieve efficient stormwater disposal.

These conditions impact on the viability of both stormwater treatment options and subdivision construction techniques.

3 STORMWATER MANAGEMENT DESIGN

The overall principle of the stormwater management is developed by using local sub-catchment management which provides stormwater treatment and attenuation within relatively small sub-catchments, typically less than 1 hectare. The outflow from each sub-catchment is piped via a pipe network which in turn discharges to the main trunk stormwater line that services the whole catchment.

The proposed treatment and attenuation is implemented close to source and follows Low Impact Design (LID) principles. The attenuation is provided throughout the catchment rather than at a small number of points, as with a typical pond system.

This local sub-catchment management approach is flexible enough to suit the proposed urban form and has been considered the best practical application for the site. An overview of the design principles of the local sub-catchment management (LSM) approach such as boundary definition, quality and conveyance is described in the following sub sections.

3.1 SUB CATCHMENT DEFINITION

The topography is very flat, as opposed to the traditional subdivision where natural topographical grade delineates the catchment boundaries very clearly. This results in the sub-catchment boundaries being defined by the road alignment. These sub catchments are small, typically less than 1 hectare, as distances between the crest and sag of roads is typically approximately 100 m. There are a total of 32 sub-catchments for this site.

The developed site lots adjacent to the roads rise above the road surface, rather than fall away, therefore all runoff falls toward the road. Sub catchment boundaries are thus located at the back of the lots and it is unlikely that any future modification to the ground surfaces within individual lots will significantly alter sub-catchment boundaries and areas.

3.2 STORMWATER QUALITY

The proposed overall approach for the stormwater runoff prior to discharge to the receiving environment is as follows:

- Source control for roof runoff i.e. avoid zinc or copper generating roofing or cladding materials
- Treatment of runoff from paved and vegetated ground surfaces (not roofs) to achieve 75% removal of suspended solids. This treatment can be achieved within the sub-catchments by one or a combination of the following stormwater management devices:
    - Grassed swales
    - Raingardens
- Stormwater treatment devices are to be located within the road reserve or designated PDC owned reserve areas.
- The site has a defined urban form, which can accommodate the LSM application of stormwater management.

3.2.1 RAINGARDEN AND SWALE DESIGN

The raingarden design has been based on the ARC TP10 guidelines with the time to pass the Water Quality Volume through the soil bed is chosen as 36 hours (1.5 days). This time (tf) has been adopted in accordance with ARC TP10, where choice between 1.0 and 1.5 days is based on considerations of amenity.

The design of the raingarden included a reduction in the depth of media from the standard TP10 approach. Collaboration with Landcare Research enabled the design to accommodate this criterion to minimize any lowering of adjacent groundwater levels and any associated increases in settlement of the peat soils. The base of the raingarden sits above the winter groundwater table and will provide some recharge capability to the peat sub soil. A review by geotechnical consultants of the likely effect of the proposed swales and raingardens on groundwater levels and potential settlement indicated minimal effects.

The natural peat nature of the sub soil was also utilized in the raingarden media. Peat is well known as a good media for contaminant and heavy metal removal therefore a media mix was designed to utilize this on-site source. The re-use of on-site soil removed the unnecessary importation of material which in turn reduced construction costs

The swales and rain gardens are generally located adjacent to roads. Alternative locations are in a number of separate reserve areas. The subdivision layout has wide road reserves, which allows the raingardens to be constructed using a formed batter, rather than vertical walls, thus achieving an economical design.

Runoff will be detained within the raingarden filter media and the water quality volume (WQV) will pond up to a depth of 200mm above the raingarden surface to achieve overall removal of 75% of suspended solids.

The preferential path for the water flow is through the filter media within the raingarden, exiting to the under drain which discharges to the pipe network. During the larger than WQV rainfall events flow will enter the pipe network via an overtopping manhole. This manhole has a scruffy dome to minimize gross pollutants (e.g. litter and leaves) entering the network. The scruffy dome has been designed to ensure that the gross pollutants fall off the grilled cover. It also has minimal height, which will result in t the vegetation within the raingarden masking the scruffy dome's r appearance and will reduce the risk of inquisitive minds entering the raingarden itself.

Swale and raingarden depths are kept shallow to minimize any lowering of adjacent groundwater levels and any associated increases in settlement of the peat soils. A review by geotechnical consultants of the likely effect of the proposed swales and raingardens on groundwater levels and potential settlement indicated minimal effects.

Stormwater runoff for the design water quality volume (WQV) storm event for a typical sub-catchment has been modelled using HEC HMS through the swale and raingarden combined. The results (of the modelling) show shallow depths of ponding, which will essentially be masked from view by the vegetation within the raingarden. This is considered acceptable from a general public amenity point of view.

The swales have a low velocity, maximum 0.25m/s, to encourage treatment facilitation of the runoff and will not cause erosion as with the overtopping of the outflow structure. The potential for localised erosion is mitigated where the flow enters the swale or raingarden by the placement of small rip rap.

3.2.2 OPERATION AND MAINTENANCE

Operation and maintenance procedures were developed specifically for the raingardens and swales for the Avenues. These address any potential problems and allow remediation to be carried as required to ensure optimum operation of the devices.

There has been extensive liaison between PDC and the developer to ensure that PDC concerns are addressed with regard to ongoing operation and maintenance of the raingardens and swales, which would become a PDC responsibility as they are within the road reserve. Extensive studies have been undertaken as to the long-term costs with respect to physical resources and monetary contributions for the implementation of the local sub catchment management approach for this development.

An extended maintenance period has been applied to the subdivision as part of the bonding process through the approvals by PDC. This ensures that the risk is reduced for the local authority that will take over an asset that has been established for 3 years and maintained in accordance with the agreed design and operation.

3.3 CONVEYANCE

There are two main parts to the conveyance of the stormwater runoff, one; to and through the recharge pits, raingardens and swales; with the other the central or main trunk line, which is the receiver of the discharge from the Avenues.

3.3.1 RECHARGE PITS, RAINGARDENS AND SWALES

Runoff from paved and other ground surfaces is conveyed initially by swales, which discharge through a raingarden to a primary piped network.

Roof water is piped to recharge pits within each private house lot, with overflow piped to the primary piped network. This is to maintain groundwater recharge, which is naturally occurring within the site under pre-development conditions. Recharge requirements and recharge pit design guidelines have been developed by consultants, which provide pit design dimensions in relation to roof area.

3.3.2 MAIN TRUNK LINE AND PRIMARY NETWORK

The overall constraint on the primary pipe network is that the receiving environment, being a piped main trunk line, has an invert level constraint. The design of the main trunk line had to consider the sub soil conditions, which is low strength peat. Construction needed to be within the first 3-4m below the ground surface with the contractors, who were consulted early in the project, preferring 3m below surface rather than 4m.

The PDC design parameters for the piped network is that the ponding within the raingardens at the entry to the piped system does not encroach onto the road carriageway for the 10 year ARI event and the 100 year ARI runoff is to be accommodated by ponding adjacent to the raingardens without crossing into private property and without causing a hazard to road traffic. .

The network is designed to convey the stormwater runoff generated from a rainfall depth associated with a 10yr ARI plus an additional 10% of this depth (thus 110% 10yr ARI rainfall depth).; however the main trunk lines that service the site and the upstream catchment are to be sized for an un-attenuated 100 year ARI peak flow rate. This was at PDC's request to ensure that the network is future proofed with respect to increasing the built environment and to minimize the risk of overland flows over a main road immediately downstream of the site.

3.3.3 ATTENUATION

Attenuation will occur due to the nature of the catchment, in particular the very flat natural ground surfaces and the associated need to provide a "hump and hollow" road alignment to ensure adequate road drainage. This in turn creates a series of small sub catchments.

Attenuation is to be provided close to the source of runoff within and above raingardens, swales, parks, reserves or roads. It is to be hydraulically designed to avoid adverse effects on public amenity and private land as well as avoiding hazards including vehicles using roads. The various design rainfall events were modelled through the sub-catchments together with the swales and raingardens using HEC HMS software. The results of a typical sub-catchment during a predicted 100 year ARI flood event are shown in Figure 1.

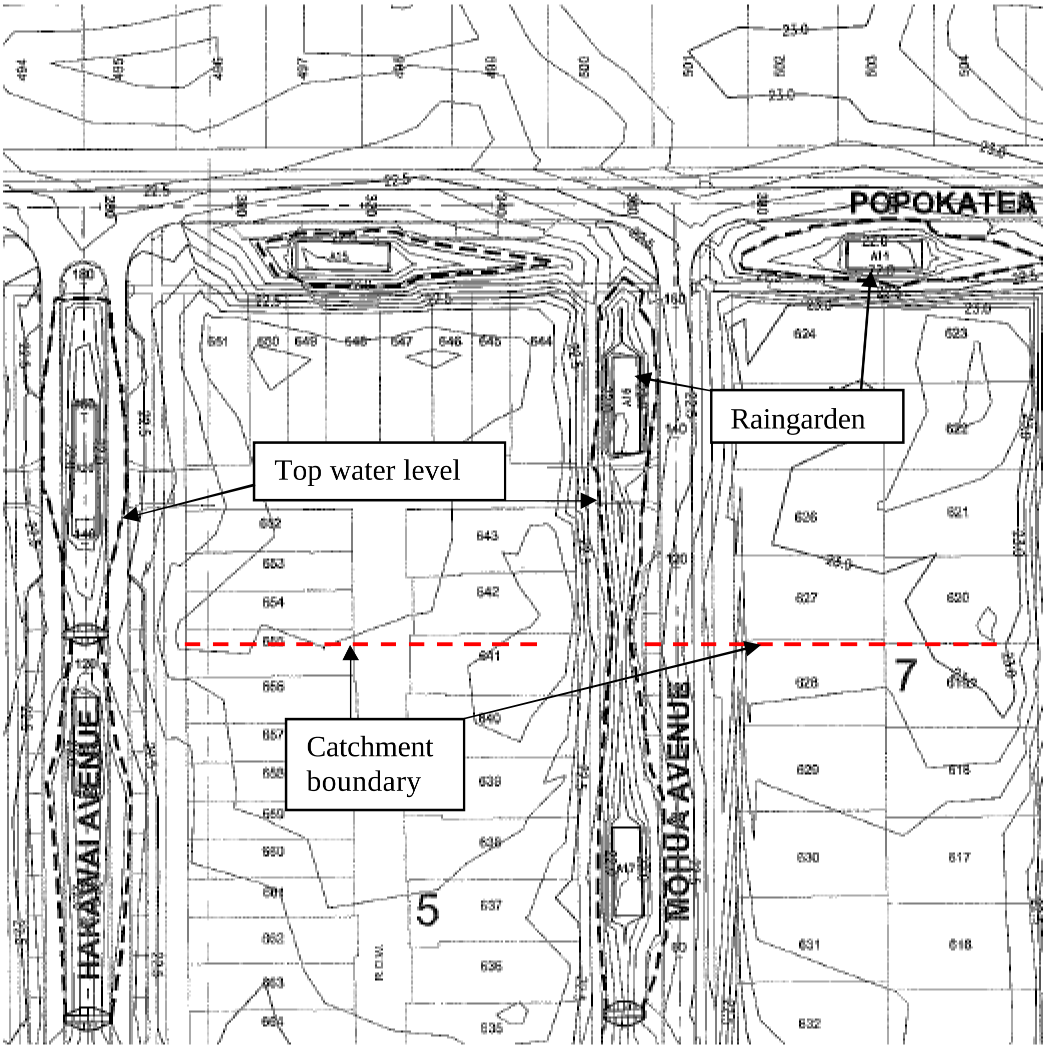

Figure 1: Plan; Extent of 100yr top water level

3.4 OVER LAND FLOW PATHS

During a 100 year event the rainfall runoff will utilise a combination of the primary pipe network, storage within the raingarden and swale surface, road surface storage for minimum periods of time as well as overtopping from one sub-catchment to another prior to discharge to the main trunk line.

The LSM approach to management of a 100 year ARI event is to provide storage within the sub catchments for attenuation. Designing the raingardens and swales together with road alignment and grades to accommodate ponding above the surface provides this storage. This storage provision will avoid flows in excess of the capacity of the primary pipe network to discharge from the sub catchments by overland flow.

The design of the swales, roads, raingardens and raingarden overflow outlets for the site addresses flooding as the volume of runoff can be safely attenuated by temporary ponding within the road reserve within the site, which also avoids private property. The maximum depth of floodwaters on the road surface is less than 200mm, which does not adversely affect amenity or cause public hazard.

The floor levels of buildings and other assets to have a minimum freeboard of 300mm above design 100 year flood levels, ensuring protection to the built environment.

To establish the effects of rainfall events greater than the 100yr rainfall event the maximum probable flood (PMF) rainfall event has been assessed. There is a provision for an over-all hydraulic gradient towards the south, which the recreational facility of Bruce Pulman Park is located. The hydraulic modeling of this event has resulted in relatively small flows crossing the downstream boundary as there is sufficient storage being provided within the sub-catchments of the site to attenuate of the extreme flows.

3.5 DESIGN DETAILS OF NOTE

There are a few details of the design that are worthy of mention with respect to collaboration of other aspects of the design team.

Several of the swale and raingarden design aspects needed to be integrated into the urban design. The practicality of the design solutions needed to respond to the site conditions and together with the experience of the construction team, solutions were designed to ensure that the urban design context remained in place. The road edge beams adjacent to the raingardens and swales as well as the swale crossings are two aspects that are detailed in the following subsections.

3.5.1 EDGE BEAMS

The entry of the road runoff to the swales and raingardens required it to be in sheet flow form to reduce the possibility of localized erosion. The edge beams were laid, without kerb, with a timber block sitting 30mm above the surface secured by bolts (into the edge beams) provided the barrier to vehicles and pedestrians entering the swale or raingarden. This option ensured that the visual context and the needs of the design remained along with ease of construction.

Photograph 1: Edge beams for raingardens and swales

3.5.2 VECHILE CROSSING OF SWALES

Vehicle crossings on the swales were required to allow access to the house lots that did not have rear entry lanes. In some circumstances the rear entry lane access was to be across swales however during design this obstruction was by avoided by altering landform slightly to accommodate treatment requirements close to source.

Shallow concrete bridges were designed to be wide and shallow enough to allow vehicle crossing without providing too much vertical curve which could damage the under carriage of the vehicle. This crossing also needed to be narrow to not reduce the treatment capability within the local sub catchment. The resulting shallow concrete arch has also removed most barriers to the passage of gross pollutants to the scruffy dome outlets.

Photograph 2: Swale crossing

4 CONSTRUCTION

The construction of the LSM stormwater system has been a collaboration of efforts from the designers through to the implementation team of the contractors. This function has been recognized from the inception of the design to ensure that successful construction of the devices results in successful long term operation. The key aspects that have been highlighted with this project are that all parties need to understand the design, select appropriate materials from the range available and make sound construction judgment with all parties' collaboration. An overview of these aspects is described in the following sub sections.

4.1 UNDERSTANDING THE DESIGN

The initial meetings on site were held with the site engineers, engineer to the contract to ensure that the details of the design were explained. With no long-term experience in the large number of low impact devices, such as raingardens, to be constructed, which totaled 42 for the project, then the importance of getting the construction correct was imperative.

Good lines of communication were established and maintained to ensure that any query was listened to and reacted on. This was an extension of the close liaison that the designers held between the civil designers, who undertook the other infrastructure aspects for the development, which latter become engineers to the project.

The site engineer for the contractors become fully aware of the details of the design and took onboard the need to apply additional supervision for the construction of the raingardens and swales.

The local authority, PDC and territorial authority, ARC, both took a keen interest in the site. The initial pre-construction meeting was established to identify the risk of the construction of the raingardens, in particular. Close supervision of the first few raingardens were held by both authorities prior to confidence being gained to relax the need to be at every construction of each raingarden.

4.2 SELECTION OF MATERIALS

The onsite peat sub soil was used to provide 50% of the material for the raingarden filter media. A stock pile was used of the imported topsoil and sand along with the peat and machine mixed onsite.

There are 42 raingardens in total requiring approximately 1600m3 of media. Importation of media would have resulted in large construction costs which would have compromised the economic viability of the project. The identification early on in the design of the onsite resource reduced the raingarden media costs to an acceptable level.

During construction the raingarden mulch (or bark) was sourced based on availability within the market, due to the large quantities involved. A selection of bark with gravel mix was undertaken in collaboration between the supplier, designer and site engineer.

Photograph 3: Machine mixing of raingarden soil media on site

4.3 OVERSEEING CONSTRUCTION

Shallow construction for the stormwater infrastructure was imperative, as identified in the design period, and confirmed during construction of a the adjacent wastewater sewer line, which is deeper than the main trunk line at 5-6m deep, however in the same sub soil conditions. This sewer line is smaller, at 525mm diameter, than the main trunk line which is between 1.2m and 2.2m diameter. Several construction companies were consulted prior to detailed design to ensure that the latest techniques were considered, however open cut, and lowering cages to work at depth, was determined to be the best practical approach.

The main trunk line was constructed by the same contractors undertaking the internal Avenues infrastructure. This experience enabled the contractor to quickly respond to the sub soil behaviour during construction of the Avenues stormwater network.

The designers remained updated as to the program to ensure that they could respond in a timely manner to any alterations that may have to occur on site due to unforeseen issues. One instance was the selection of mulch to match the consented requirements. A supply issue meant that decisions needed to be made relatively quickly to supply the quantity for the site's needs.

5 PROJECT STATUS

The first stage of The Avenues has been granted 224C by PDC with the remaining final stage, which equates to two thirds of the project awaiting the 224C at the time of writing.

6 SUMMARY

The flat topography together with peat sub soil conditions lead to a local sub catchment management approach to the stormwater treatment and discharge. The runoff is required to be treated prior to entering the receiving main trunk line, which is achieved by filtration through raingarden and swales along with source control for roof runoff. Recharge pits allow for groundwater recharge ensuring that the sub soil conditions and water tables remain as per pre development status.

The design of the at-source water sensitive urban design (or low impact) stormwater management, met the requirements of the regulatory authorities as well as the needs of the urban design team for the Avenues development. A collaborative approach, of all the development team consultants, was implemented at the design stage to provide the best practical application of stormwater management for the Avenues residential subdivision.

Specific details associated with the design of the raingardens and swales allowed for the urban context to be maintained between stages of the overall Addison development in Takanini.

The construction phase was undertaken with close supervision and liaison with the designers. This enabled all parties involved with the construction to have a great understanding of the required outcomes with respect to levels of treatment and stormwater management device performance.

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