BEACHLANDS DEVELOPMENT PROPOSAL URBAN DESIGN AND LID STORMWATER SCHEME

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ABSTRACT

Designing subdivisions is increasingly challenging for civil engineers. Available sites are becoming scarcer through increased demand for urban development conflicting with efforts to reduce urban sprawl. At the same time we are challenged with an increase in environmental awareness and a desire to develop in sympathy with nature.

LID (low impact design) principles can be applied to new subdivisions in lieu of traditional piped systems but with the added benefits of more natural hydraulic relationships and increased contaminant control whilst still providing for the semi intensive development necessary to limit urban sprawl. LID also integrates with urban planning to provide developments with a high degree of amenity. Auckland University Civil and Environmental Engineering students enrolled in Urban Stormwater Management, submitted entries in a design competition involving the hypothetical development of a 32 hectare greenfields property in Beachlands.

This winning entry provided for 347 residential lots and a commercial zone whilst still providing a high degree of connectivity and open recreational space for residents.

This paper covers stormwater control methods, LID treatment devices, hydraulic modelling and urban design principles utilised to produce a subdivision that not only meets legislative requirement but also creates a place we would like to live in.

KEYWORDS - Urban, Low Impact Design, University, Stormwater, Environment

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1 INTRODUCTION

New Zealand, and in particular Auckland, has an expanding population. However suitable land for development to accommodate this population growth is becoming scarcer. Areas prime for development are increasingly further from the CBD resulting in urban sprawl. As a result infrastructure, services and transportation are stretched.

In an effort to limit urban sprawl, engineers are faced with the challenge of developing sites at higher densities than traditionally achieved. With this increased density comes a higher degree of imperviousness, greater loss of vegetation, loss of natural habitat and elevated contaminant production. All of this at a time when the community in general is becoming more aware of the environment and more concerned about the impact we have on it.

Engineers are responsible for designing environmentally sound subdivisions on land that might have been considered undesirable for development in the past and traditional piped network design approaches do not necessarily provide all of the desired outcomes anymore.

Low impact design (LID) is an alternative design philosophy where the primary objective is to minimise the impact of a development on it its natural environment. LID principles are applied with the intention of ensuring that a subdivision does not contribute to hydraulic or environmental degradation of its immediate development area. Furthermore, LID goes beyond the development boundaries and considers the wider catchment and the receiving environment as well.

The hydraulic principles of LID begin with minimising imperviousness. By doing so, stormwater infiltration is maximised and conversely runoff is reduced. Limiting compaction, conveyance without pipes, detention, enhancement of evapotranspiration and reduced imperviousness all contribute to hydraulic neutrality with the pre-development state.

The environmental principles of LID include filtration of stormwater contaminants, minimising earth disturbance and sediment production, reducing vegetation removal and the protection of watercourses.

Further to the hydraulic and environmental principles, LID philosophy goes beyond stormwater control and can be extended to encompass good urban design and development in sympathy with nature with the provision of more green space.

LID designers have a number of tools in which to control the hydraulic, physical and chemical characteristics of stormwater runoff. These tools or 'devices' have different attributes and can be applied to various situations for different desired outcomes. Devices can also be strung together as a treatment train further improving their effectiveness. Some of these devices are raingardens (bioretention cells), grassed and vegetated swales, permeable pavement, green roofs and detention/retention tanks.

University of Auckland engineering students enrolled in the postgraduate paper "Urban Stormwater Management" were given the opportunity to design and develop a hypothetical subdivision scheme using LID principles on a real rural block of land in Beachlands, Auckland. The development parcel was a 32.5 hectare site of pastoral land (figure 1) with moderate to gentle sloping topography and two ephemeral valleys combining at a confluence into a perennial stream.

Figure 1: Site location.

Students were asked to provide a roading layout over the site taking into consideration natural features and an assigned commercial area. They were then tasked with locating a very specific and generous number of residential lots keeping in mind basic urban design principles and ultimately developing an LID stormwater scheme for the entire site.

This paper is a brief insight into some of the key features, design procedures and outcomes of the submission that won Auckland Councils Student LID design competition in 2012.

2 LID AND URBAN DESIGN PROCESS AND CONSIDERATIONS

2.1 AMENITY AND URBAN LAYOUT

While the focus of the University study was on stormwater control it was important to consider the urban design of the development to ensure that the end result was actually something that was liveable and marketable. In real world examples, engineers need to work with architects early in the design process. This mixed discipline approach was reflected in the project work as well.

2.1.1 DESIGN PROCESS

At the beginning of the design process ecological and recreation reserve boundaries were placed around the stream margins. Following this, preliminary road layouts were arranged taking into consideration contours and the need for connectivity over the site. The remaining zones were available for commercial, residential or recreational use. Refer to figure 2.

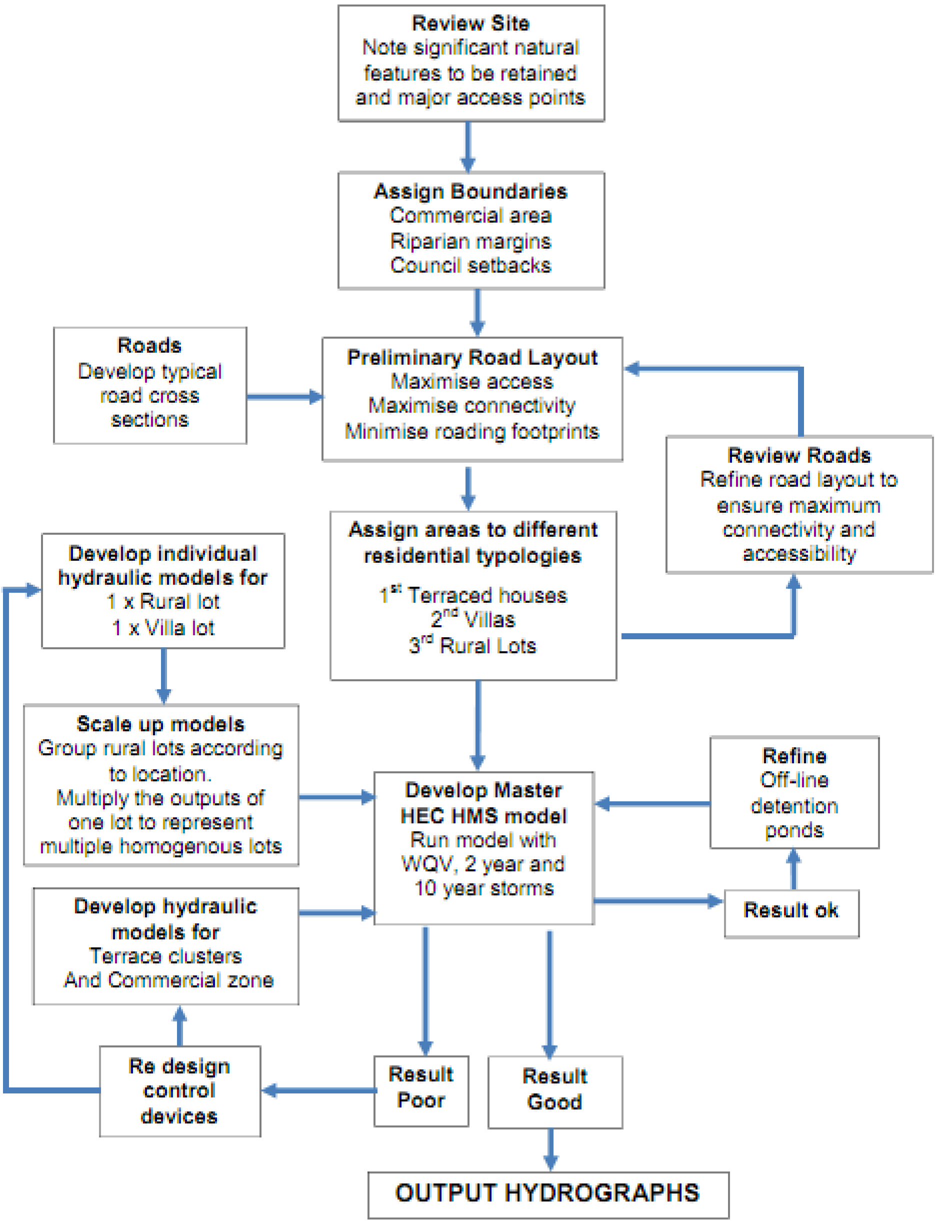
With a fixed commercial zone requirement of 3.2 hectares and the strict extensive residential requirements, the greatest challenge became preservation of parks and managed or manicured recreation space.

2.1.2 PARKS AND RECREATION

In this hypothetical subdivision a central 'heart' of flat and highly buildable land was set aside for community use as small sports grounds. On balance it was the author's opinion that the amenity that this park brought to the subdivision more than offset the loss of saleable real estate. By providing a more livable community the remaining residential lots would be more marketable.

As a contrast to the urban recreational area offered by the central park, the valleys provide for more lineal urban activities such as jogging and walking through a natural bush and stream setting. Boardwalks, managed tracks and frequent access points help make these vegetated areas highly accessible and would ensure they were well utilised and subsequently well cared for.

Figure 2: Design process.



2.1.3 RESIDENTIAL TYPOLOGIES AND LOCALE

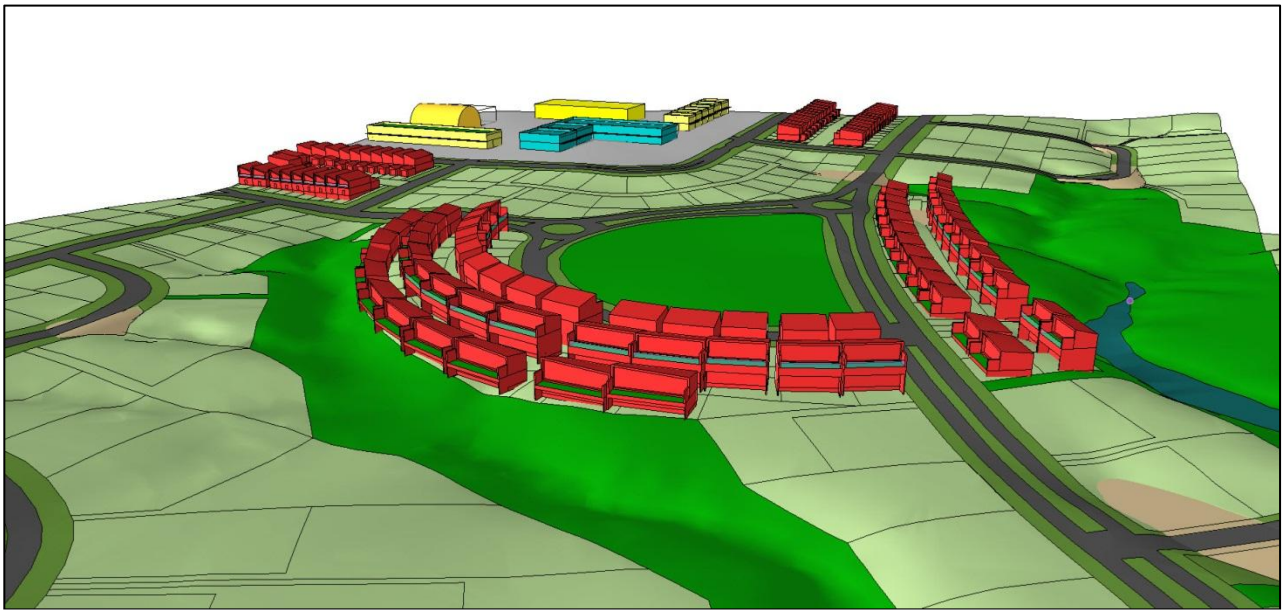
The design challenge was to provide 125 800m^2 rural lots, 112 352m^2 villa lots and 110 205m^2 terraced house lots, all on the 32.5 hectare parcel with provision for commercial zone, recreational and ecological spaces and sufficient roading network to provide a high degree of connectivity and accessibility.

To meet this challenge the three housing typologies were grouped according to urban design principles and topographical challenges. Higher density housing was located closest to the main arterial routes and to commercial amenities whilst the larger "kiwi dream" rural lots were located more distally from the commercial end.

High density terraced lots were subdivided into two smaller sub categories each having different needs and therefore could be clustered at different locations on the subdivision. Some no fuss terrace house blocks were located close to main arterials and commercial zone while some 'higher end' blocks were located closer to the park and recreation. This latter group had wider more attractive vistas and were often staggered to give better views.

No matter where the terraced houses were located saw tooth roof construction and general northerly aspect ensured that maximum light was achieved given the constraints of shared wall construction. See figure 3.

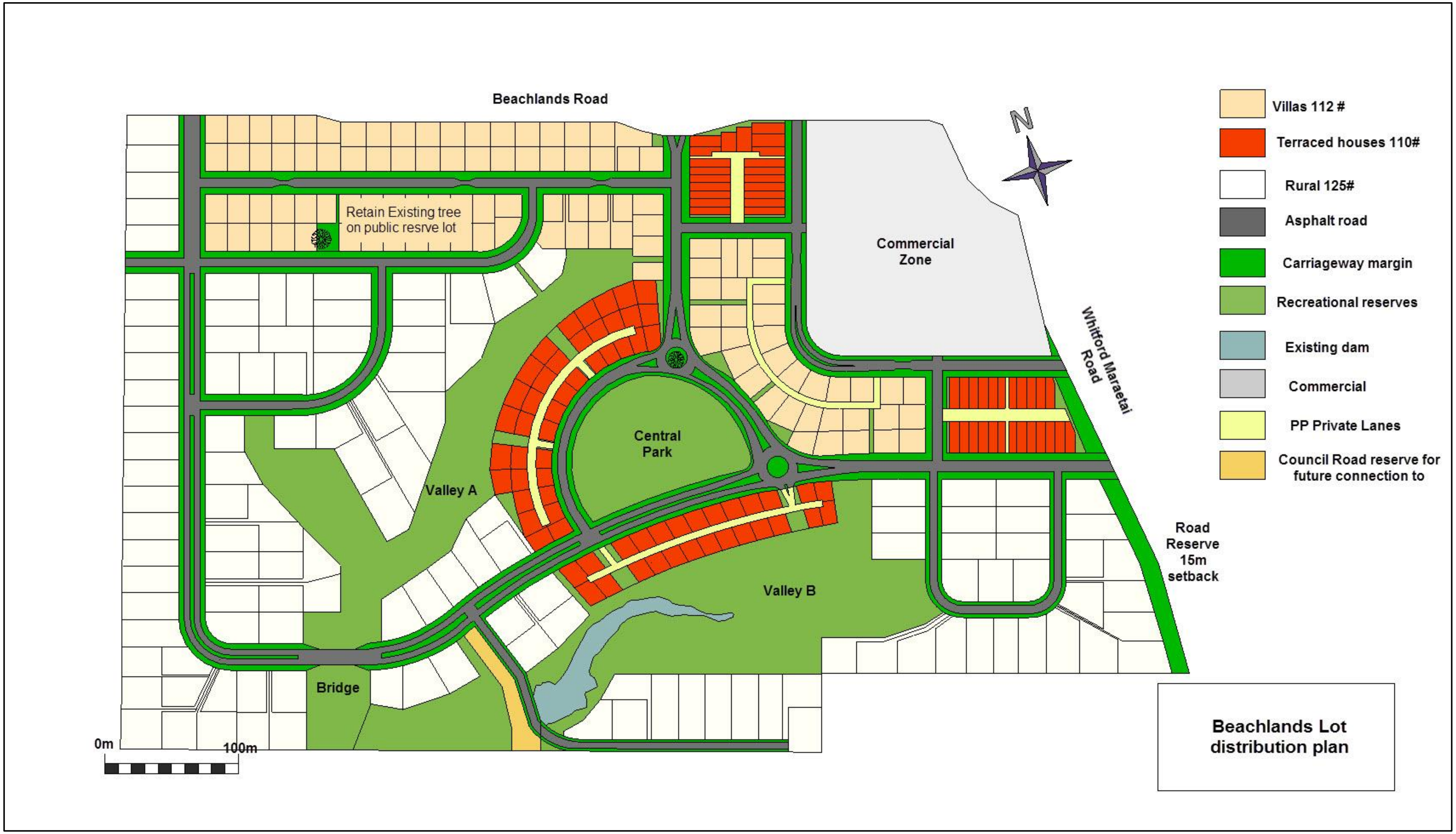
Figure 3: Terraced house typologies illustrating orientation to north, to valley or central park vista or conversely located convenient to commercial area (in blue and yellow beyond). Image viewed from west.



From a topographical point of view it was both the larger rural lots and the high density terraced lots that lent themselves to construction on the steeper or more difficult to develop regions of the subdivision, but for slightly different reasons. The terraced houses having significant ground works could be built into a hill side whilst for the rural houses there was generally room for selecting a favourable building footprint within the 800m^2 section. Conversely the villa style of construction required plots that were relatively well ordered and level due to the small plot size relative to freestanding house footprint.

Terraced house clusters were assigned to their two types of location after the preliminary road layout. Villa lots came next and were located on the most level and geometrically ordered sections. These villa zones were located within walking distance of the main arterials and services. Lastly the rural lots were assigned to the areas most distant from the commercial zone. See figure 4.

Figure 4: Site Layout.



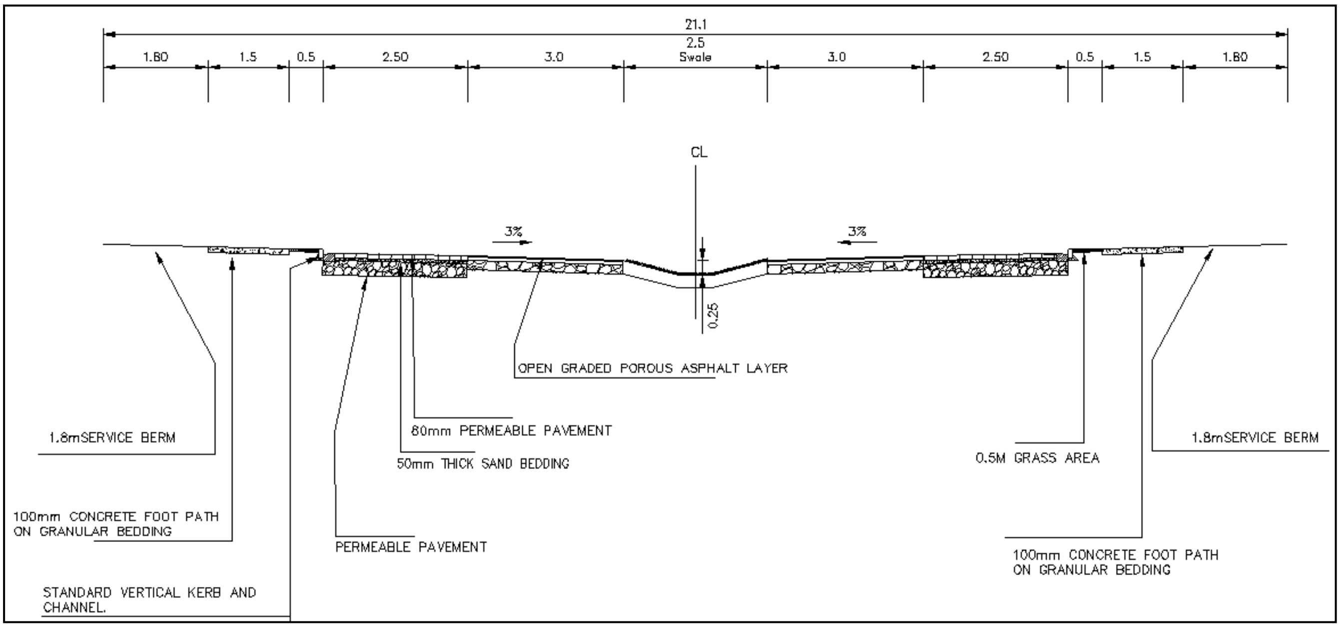
2.2 ROAD LAYOUT AND STORMWATER CONTROLS

2.2.1 GEOMETRY & CROSS-SECTION

The focus of design was to minimise impervious surfaces to an extent which would not adversely affect the driver safety and comfort as well as the amenity value of the subdivision. The roading network was arranged to follow the existing contours in order to minimise earthworks and enhance driver comfort. The network was intended to provide public access to the reserve areas and linkage to the existing roads surrounding the development and future access to Pine Harbour Marina.

Road cross-sections were chosen to comply with the minimum legislative requirement of former Manukau City Council Plan Change 30: Beachlands Village New Avenues BVNA width requirements. Cross-sections were modified to incorporate a number of LID devices in road corridor for creating “green streets”. As a minimum, each road has a swale and permeable pavement car parking area on one or both sides. Bio-retention cells were also proposed in the roundabout inner circle and also in the planted berms between permeable pavement side parking. Typical road cross-section is shown in Figure 5.

Figure 5: Typical Road Cross-section



2.2.2 SWALES

Dry grassed swales, designed to carry WQV and provide conveyance during the $2_{yr\text{-}24hr}$ and $10_{yr\text{-}24hr}$ design storms, were provided in all road corridors. Swales not only provide conveyance but they are also effective in water quality treatment. The ARC Contaminants Loading Model showed that a 100m long road swale reduced TSS by 75%, Zn by 50%, Cu by 100% and TPH by 44%. Further reduction was seen when a second LID device was added in a treatment chain.

Generally swales were proposed at the centre of road cross-section, which not only provided a stormwater management function but also provided a barrier between opposite traffic as well as being a planted landscaping feature that enhance amenity.

Having said that, the use of swale as WQV treatment device had a number of constraints, and in some instances it couldn’t be applied effectively in this subdivision. Hydraulic Retention Time or HRT is one of the main limitations of swale. Achieving the 9mins recommended for WQV was not possible with the steeper existing grades. To overcome this problem check dams were designed, to be installed at regular intervals in order to minimise the hydraulic slope and reduce water velocities.

The flow velocity during conveyance is another limitation of the swales in this subdivision. To achieve the maximum flow velocity of 0.3m/s and 1.5m/s for WQV and conveyance respectively, in some instance very wide swales were required. Based on the limited space available it was not easy to provide wider swales. By providing check dams and reducing the free board the flow velocities were reduced to acceptable limits.

2.2.3 PERMEABLE PAVEMENT

Permeable pavers (PP) were used extensively throughout the subdivision. PP were used in roadside car-parking, intersections, residential driveways and private and public lanes. The objective of PP at intersection was to provide a visual warning of the upcoming change in the road cross-section and skid resistance. PP also provided an aesthetically attractive surface, as well as providing stormwater detention and minor treatment function.

Some of the limitations of permeable included the following. Sediment-laden runoff can clog pervious pavement causing it to fail. Constant pressure in the same spot (regular vehicle braking) can wear the edges of pavers. The resulting paver ‘dust’ can migrate into the substrate and clog the base course and the reduced paver size can result in them becoming loose. Installing permeable pavement on main road is considered a driving hazard as pavers could be unlocked and pose a hazard to road users. PP is limited to low traffic areas with limited structural loading. Load capacity is not high as the pavers available on the market have lower than required loading capacity.

2.3 RESIDENTIAL AREA AND STORMWATER CONTROLS

The purpose of this project was to provide for 347 residential lots on the 32.5 hectare parcel. Residential lots took the majority of the subdivision area, hence it was necessary to deal with the stormwater at the source point and eliminate runoff from residential lots in all minor events where possible.

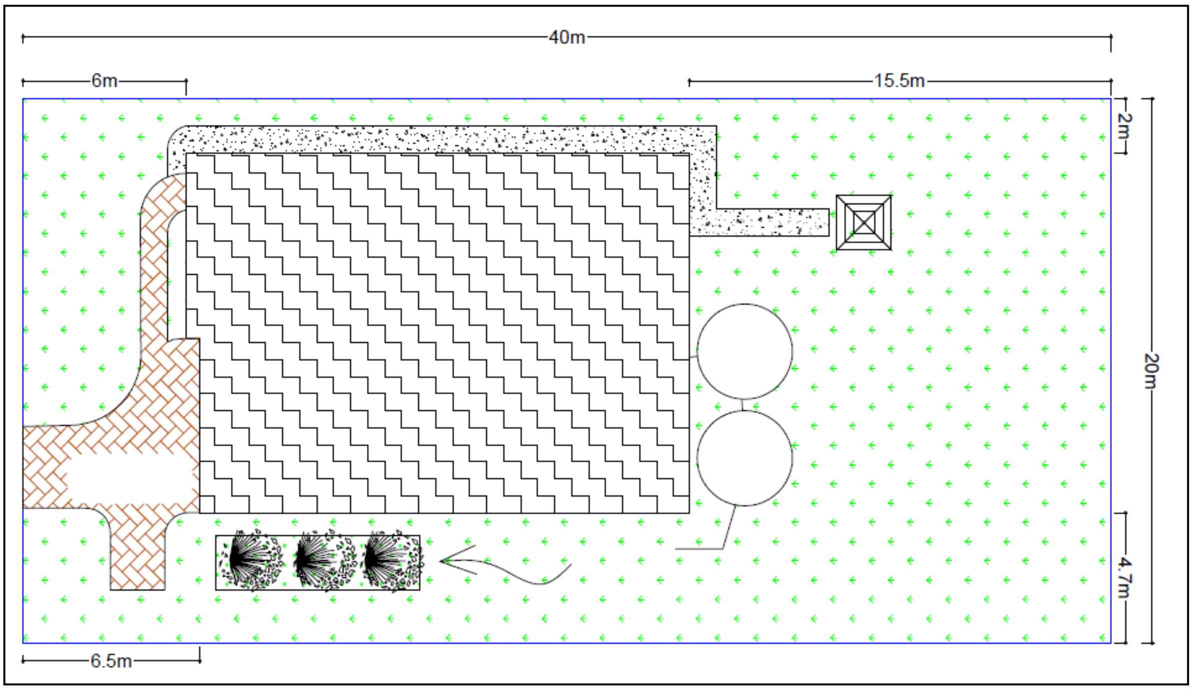
2.3.1 RURAL LOTS

A number of different stormwater management devices were incorporated in residential rural lots to treat run-off from roof and driveways. A typical layout of a rural lot is shown in Figure 6.

It was proposed to put two 25m^{3}water tanks to collect rain water from roof and re-use for all domestic requirement. The overflow runoff from tanks was diverted to a bio-retention cell which also managed stormwater from other impermeable surfaces.

In order to keep the impervious surfaces minimum, shared access ways were proposed where possible and all driveways and parking areas were be constructed of permeable pavement blocks.

Figure 6: Typical Rural Lot Layout



To minimise the impervious surfaces, common permeable paver driveways were proposed and at a minimum, two lots used the same right of way driveways. Another reduction in permeable surfaces was achieved by reducing the front yard thus shortening the driveway length.

Finally Bio-retention cells were incorporated in the stormwater management chain to manage overflow from tanks and runoff from the permeable pavement.

Each lot also had a minimum of 15m^2 of Rain Garden or Bio-retention cell. These gardens contributed to the amenity value of the lot, as well as treating stormwater runoff at the source. While bio-retention cells were not strictly required from a treatment perspective due to the low level of contaminants in run off from rural structure, they do provide very good hydraulic function with high evapotranspiration and enhanced infiltration.

Installing rain gardens had some limitations at the design and implementation stages. Firstly, there is no validated model available to evaluate rain-garden hydrology in the HEC HMS software. Instead a stage discharge excel spreadsheet model was adopted. Secondly, installing rain gardens could be challenging as it would be difficult to enforce legislation to maintain these devices in good working condition.

2.3.2 VILLA LOTS

Like rural lots, the villa lots relied on the use of permeable paving and detention however there was insufficient room to have significant retention on the smaller 352m^2 sites. As a result there was no recycling of water on these mid-sized sections.

With a slightly larger ratio of impervious to pervious footprint when compared to the rural lots, the devices chosen had a greater focus on volume control.

2.3.3 TERRACED HOUSE

Terraced houses are smaller in land area compared to rural lots. The terraced houses were high density residential complexes with property sizes of 205m^2 or greater. In this development there were four clusters of terraced houses each cluster with its own private paved (PP) service road so as to minimise the number of street crossings required.

Similarly to rural lots, in the terraced houses different LID devices were proposed to control runoff at the source.

A semi intensive (deep bed) green roof system was chosen for WQV treatment as they provide small amount of storage and enhanced evapotranspiration. These green roofs suited the terraced house typologies for two reasons. Firstly the construction of terraced houses with narrow profile and tilt slab concrete walls gives good structural support for the substrate as compared to conventional timber framed building design. Secondly the terraced houses have limited green space and by providing a balcony accessed green roof on the northern side, tenants are able to establish a small private garden area. By providing a deeper root bed and good maintenance access, the green roof can be planted with a greater variety of less hardy species making it more versatile than conventional roof top green roofs.

It was proposed to install an underground lined concrete detention and storage tank with a first flush control system. This supplies water for toilet flushing and for non-potable end use around the entire complex including watering of the green roofs in dry weather. A 40mm orifice half a metre up the tank ensures 30,000L is available for non-potable end use whilst the remaining 1.5 metres is used for detention and 200mm overflow at the very top.

Because of the body corporate ownership and group responsibility for water quality, the use of stored water for potable use was not considered appropriate in the terraced houses unlike the rural lots where the owner is directly responsible for maintaining their own water purification and maintenance of water tanks.

2.4 COMMERCIAL AREA STORMWATER CONTROLS

Commercial areas differed from residential areas primarily because of the need for extensive car parking. With this vast surface area and frequent vehicle movements comes a high degree of contaminant production. For this reason bioretention cells were the device of choice because of their very successful contaminant removal through physical filtration and biofiltration.

In addition to the bioretention cells permeable paving was most useful on the car spaces themselves and it was feasible to add green roofs to some of the smaller shops. The larger warehouse construction of supermarket and large retail stores did not however have the support necessary for green roof loads. On these larger structures the use of zinc products was minimized.

2.5 HYDROLOGICAL CONSIDERATIONS

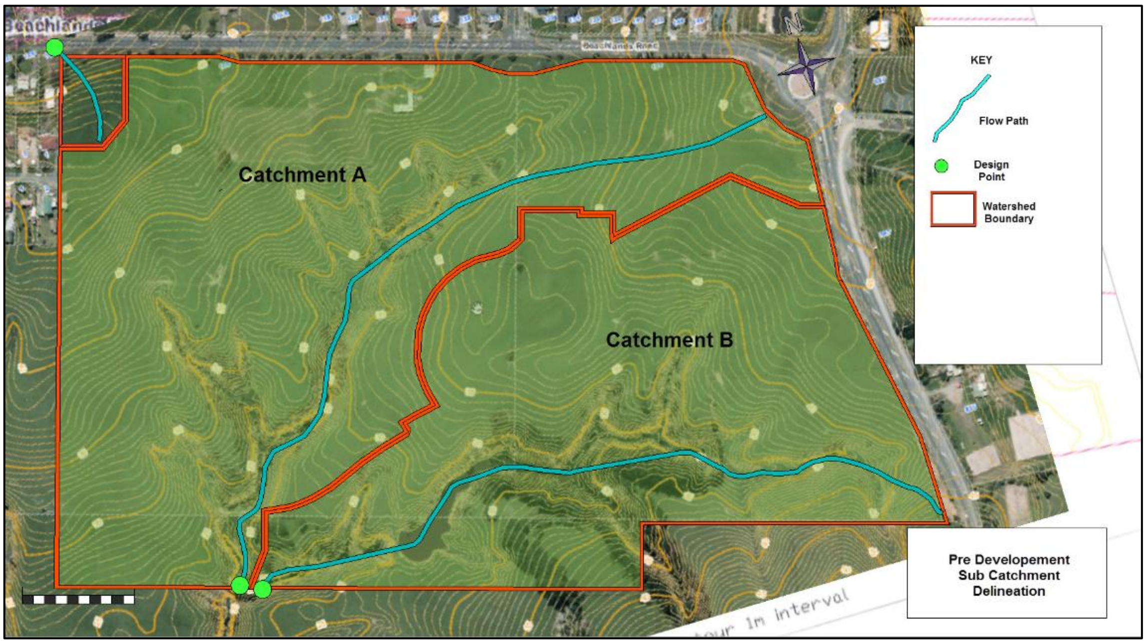
In the project our goal was to adhere to the principles of LID by minimisation of impervious surfaces, controlling at source, protecting waterways from increasing/excess erosion, encouraging infiltration, water extractions and diversions, in order to match post development with pre-development condition hydrographs. The aim was to match hydrographs for the WQV event, 2 year event and 10 year event.

Matching pre-development was carried out by way of reduction of surface runoff by interception, evapotranspiration, infiltration, or capture and reuse of stormwater in gardens or directly consumption as potable or non-potable supply.

Moreover the intention was to maintain the water balance and groundwater recharge improve water quality therefore protect aquatic resources from several indirect impacts of the land development process, including decreased groundwater recharge, decreased baseflow and degraded water quality.

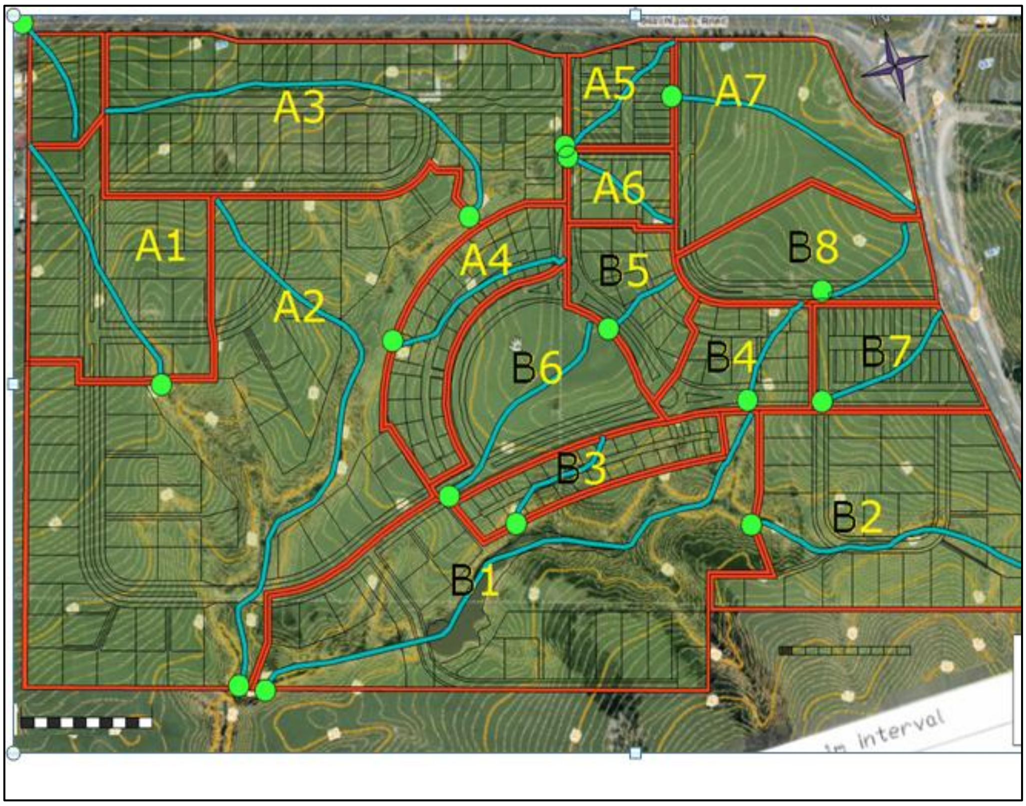
Catchments were delineated for the pre and post development situations (Figures 7 and 8) and overland flow paths were defined.

Figure 7: Pre development catchment delineation



Based on the proposed layout of the project, it was calculated that about 1/3 of the pre developed ground was to be covered by impermeable surfaces (i.e. roofs, roads and driveways). The alteration in the site coverage undoubtedly indicated an expansion in the surface runoff volume and drop in time of concentration flow.

Figure 8: Post development catchment delineation



To compare undeveloped and developed site runoff and to estimate of the effects of development, complex hydrological models using HEC HMS (Figure 9) were developed with summary results shown in Table 1.

Figure 9: Post development HEC HMS model based on subcatchments shown in figure 7

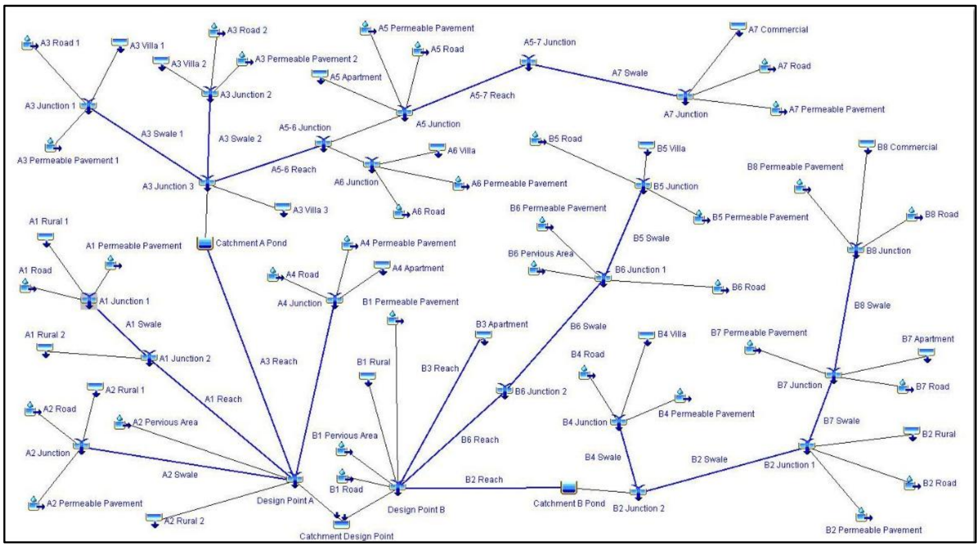


Table 1: Resulting runoff from three storm events for pre and post development .

Catchment A	**WQV**		**2 Year**		**10 Year**	
	Pre-Dev	**Post-Dev**	**Pre-Dev**	**Post-Dev**	**Pre-Dev**	**Post-Dev**
Peak Flowrate (m^3/s)	0.0798	0.1863	0.7605	0.9185	2.0617	1.9782
Volume (1000 m^3)	0.659	1.594	5.552	7.885	14.674	17.795

Catchment B	**WQV**		**2 Year**		**10 Year**	
	Pre-Dev	**Post-Dev**	**Pre-Dev**	**Post-Dev**	**Pre-Dev**	**Post-Dev**
Peak Flowrate (m^3/s)	0.0614	0.1244	0.585	0.6274	1.5859	1.6648
Volume (1000 m^3)	0.507	1.122	4.271	6.267	11.288	14.161

Whole Catchment	**WQV**		**2 Year**		**10 Year**	
	Pre-Dev	**Post-Dev**	**Pre-Dev**	**Post-Dev**	**Pre-Dev**	**Post-Dev**
Peak Flowrate (m^3/s)	0.1411	0.3097	1.3456	1.5435	3.6476	3.643
Volume (1000 m^3)	1.167	2.716	9.822	14.152	25.961	31.955

Ultimately this design required the installation of two detention ponds which were strategically added at the head of the ephemeral gullies in order to minimise earthworks and attempt to control volume as close to source as practicable.

2.6 ECOLOGY OF THE DESIGN

2.6.1 EXISTING LAND USE

The subdivision location is on the residential rural fringe. The existing land use was farmland and although considered a greenfields development from an engineer's point of view, from an ecological and hydrological perspective it was already significantly modified. Whilst this presented challenges in its own right it also provided the opportunity to create a subdivision with improved hydrology and ecology by utilizing LID principles.

2.6.2 RIPARIAN PLANTING

The two ephemeral valleys suffered from large vegetation removal, weeds, over exposure to sunlight, pugging from stock and erosion of sediment. Native fauna or flora was almost non-existent.

In this proposal, heavy native riparian planting was proposed down the margins of both streams. The planting provides shelter and shading to the stream which is important for weed and temperature control. Further advantages are pre-filtration for water entering the watercourse, habitat for flying and swimming species, increased surface roughness providing a hydraulic detention role and stabilisation. Many of these attributes may go un-noticed by the developer and residents however the visual amenity that planting provides is not so easily overlooked.

Figure 10: Site Layout including roading, commercial zone (grey) and recreational green space.

2.6.3 MINIMISING EARTHWORKS

Whereas most subdivision proposals rely on bulk earthworks to create an ordered and buildable subdivision, this Beachlands proposal was laid out in sympathy with the contours and required very little working of the earth. This has the advantage of minimizing any erosion and sediment transport while also leaving the ground less compacted and thus more accommodating of infiltration which is critical to LID principles. Figure 10 illustrates the 10 minor earthworks areas that were required to facilitate practical and safe roading layout in the proposal. These earthworks were confined to bridge abutments, roads crossing valley heads and retained earthworks for terraced houses.

2.6.4 FISH PASSAGE

Many of New Zealand's fresh water fish species require connection to the ocean to complete their life cycle. Smooth channelised streams, culverts, weirs and dams all serve as barriers to these migrations and as a result the numbers of these predominantly whitebait species are in decline. Because of urban sprawl and farming practices it is difficult to find completely unmodified streams in the Auckland region and this stretch of stream in Beachlands was no exception.

To facilitate fish passage in the student proposal, watercourse crossings were minimised and where absolutely necessary achieved with bridges rather than culverts. Off line detention basins were favoured over on line detention and dams.

It was noted that downstream of the development the stream is routed through a broad shallow pond and then into a concrete lined channel before discharging adjacent to the Pine Harbour Marina. (Figure 11)

Figure 11: Modified Stream bed downstream of study site

Whilst the poor connectivity downstream of the study site is considered a major obstacle to fish passage, it is hoped that in the future greater recognition of this issue may result in reinstatement of the stream. On this basis it is prudent to design the upstream reaches to a higher standard on the assumption that the lower impasse will be addressed in the future. Daylighting of culverts and restoration of stream beds are some of the issues facing stream management in the Auckland region now and into the future.

2.7 RECOMMENDATIONS

2.7.1 POST-CONSTRUCTION MONITORING

LID devices are constructed with specific hydrologic design goals and calculations. Unfortunately, data is rarely gathered from these installations or collected data is rarely published in peer-reviewed journals and are more commonly published in conference proceedings only (Bachmann 2007). Experimental modelling of hydrograph outputs from treatment devices in order to accurately model them for inclusion in HEC models rather than using proxy excel stage discharge type models would enable more realistic models to be developed.

Monitoring of actual contaminant removal performance is also required in order to help develop and establish a level of confidence in LID as a successful alternative method of stormwater treatment. At present there is very little New Zealand literature to support the long term benefits of LID subdivisions and as a result many engineers will continue to select certified proprietary equipment over designing LID devices due to perceived risks.

3 CONCLUSIONS

Although many of the LID devices have a broad range of suitable application it was generally found that some devices are more suited to specific elements of land development than others.

In this hypothetical work it was found that permeable paving was most useful in domestic use on driveways where contaminant treatment is not critical and where traffic volumes low.

Swales were most useful in a roading situation because of their ability to both treat and convey water however they had some limitations. Developing them into vegetated swales with enhanced infiltration would further the contaminant removal efficiencies.

Commercial zones with high traffic numbers and large carparks suited raingardens for their high level of contaminant treatment coupled with good retention and detention capabilities.

For terraced houses with heavier construction, green roofs were an option and detention/retention tanks feasible with small community based water supply systems. Contaminant removal on the other hand was not so critical for this type of development.

This hypothetical design exercise as part of the Urban Stormwater Design course offered by the University of Auckland, was a valuable insight into the complexities of developing a subdivision design from scratch. It highlighted the need for engineers to look at stormwater control holistically and in conjunction with urban design, developer needs and legislative requirements.

ACKNOWLEDGEMENTS

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Bradley Blucher co-author of the Urban Stormwater Management course submission.

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