KEY FACTORS TO BE CONSIDERED FOR THE PROPER DESIGN, CONSTRUCTION AND MAINTENANCE OF STORMWATER INLETS AND OUTLETS

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ABSTRACT

Auckland's public stormwater network contains more than 120,000 inlets (including about 90,000 catchpits) and outlets. These inlets and outlets play a vital role to the performance of the public stormwater network, as their performance determines whether the surface runoff can effectively enter or exit the system.

Many years of field observation by the authors indicate that the performance of a number of the stormwater inlets and outlets has been a contributing factor in some flooding incidents, mostly due to their design, construction or maintenance. These inlets and outlets have also resulted in land erosion and amenity problems. To minimise these issues in future, a technical report on inlets and outlets for stormwater quality management systems has been prepared to assist in the better performance of these vital assets.

This paper summarises the common but important aspects needing to be carefully considered in the design, construction and maintenance of the following types of inlets and outlets; catchpits, inlets from open watercourses to pipe networks, inlets and outlets of stormwater treatment devices, stream outlets and beach outlets. The aim is for inlet and outlet related flooding, erosion, maintenance and amenity problems to be avoided in the future.

KEYWORDS

Inlets, outlets, blockage, inlet controlled system

PRESENTER PROFILE

Frank Tian, a chartered professional engineer, is currently Auckland Council’s Northern Stormwater Operations Manager. He received a PhD by studying stormwater related environmental issues from the University of Waikato in 1997. Since then he has been working in the stormwater management area as a scientist, a council employee and a consulting engineer.

1 INTRODUCTION

Inlets and outlets of a stormwater system are used to provide a transition between different elements of the reticulation network (open watercourses and pipes), treatment devices and the receiving waters, either a watercourse or the sea.

Auckland's public stormwater network includes about 90,000 catchpits and 33,000 other types of inlets and outlets. They are a critical part of the stormwater system and can affect if runoff can get into the network, network safety, treatment device effectiveness, and whether erosion or other environmental problems occur. They also offer the space and opportunity to provide energy dissipation and mitigation measures to address high velocity stormwater flows, safety, or other operational issues.

Based on the author's field observation over many years, performance of the stormwater inlets and outlets has been one of the contributing factors to some flooding incidents, particularly those resulting from moderate storms whose rainfall intensity is significantly lower than the designed capacity of the stormwater network. Such inlets and outlets could also result in stream bank and beach erosion. The lack of provision of secondary overland flow paths is another important contributing factor to the reported flooding problems. This has been discussed in detail recently by Carter (2013), Irvin and Brown (2013) and Tian *et al (*2013).

This paper intends to summarise the common but important aspects which need to be carefully considered when inlets and outlets are designed, constructed and maintained. This includes:

- Catchpits;
- Other types of inlets (open watercourses to pipe networks and ponds to pipe networks); and
- Outlets (discharging to streams and beaches).

The purpose of this paper is to help increase the awareness towards these issues and focus on the key factors to be considered in order that the design, construction and maintenance of inlets and outlets can achieve the required performance in the future.

2 CATCHPITS

Catchpits are a special type of inlet to the stormwater network, particularly for the road drainage system. Due to the huge number of catchpits and their importance to the entire stormwater network, we discuss the catchpits related issues separately.

In practice, the following common issues in relation to catchpits have been encountered:

1) Inadequate catchpits – This problem is normally found in the developed urban area. There are two types of issues: (a) the spacing between two road catchpits is too great. For example, in northern Auckland, a garage was flooded several times by road runoff (where the road is located in a flat area and receives little runoff from adjacent land). Field investigation revealed that there is only one standard road catchpit in front of this garage and no others within 200m in either direction. As this is a busy arterial road, the problem could only be rectified when the road is upgraded. (b) For some flooding incidents, the catchpit spacing is not a problem, as they do meet the current design standard for road drainage. The problem is that the road design standards only consider the runoff from within the road. When a road receives a large quantity of extra runoff from the adjacent higher lands, the catchpits can not cope, even though the outlet has adequate capacity.

2) Inappropriate location – From time to time, we see some catchpits in inappropriate locations, either higher than the surrounding area or in a location where the majority of runoff will bypass the catchpit.

3) Standard catchpits on steep roads – On a steep road, where the gradient is > 5%, the velocity of runoff flowing along the kerb and channel is quite high, particularly during heavy rainfall. For a single standard catchpit, fast flowing runoff along the kerb and channel may bypass. This is more likely when the upstream side of the catchpit has some debris accumulated which can occurs very often during a windy day. The debris functions as a "springboard" for the fast flowing runoff which will then "jump" over the catchpit.

4) Catchment land use – The land use of a catchpit's catchment, mainly pavement and vegetation, can also affect performance. One typical situation the authors are aware of is a location where there are several huge pine trees within the catchment of a road catchpit. The large quantity of pine needles often "fill up" the catchpit sump, block the outlet pipe, and can even fill up the entire catchpit.

5) Catchpit maintenance – When we drive in the urban area, we often see the catchpit grilles blocked with tree leaves and other debris. This will not allow runoff to get in when it is raining and surface water ponding will result.

To overcome the above mentioned catchpit related problems, the following actions are suggested when we design, construct and maintain catchpits:

1) Treat the design standards regarding maximum catchpit spacing in the same way as we treat the maximum vehicle speed on road. It is a limit, rather than a target.

2) Fully understand the nature of the contributing catchment to a catchpit and the potential impacts of this on the performance of the catchpits, particularly the slope, vegetation, the potential coverage by vehicles, and extra runoff from the adjacent higher lands if it is a road catchpit.

3) Take a design approach for catchpits that incorporates some amount of redundancy. Figure 1 shows an example of redundant design of the catchpits in an overseas city, where the number of catchpits per square metre contributing catchment is high.

4) Take a common sense approach when installing a catchpit – consider where the runoff comes from and whether it can be intercepted by the catchpit, before designing the installation. This is particularly important for contractors or drain layers who often work for the development community.

5) Identify the potential "problem" catchpits and maintain them proactively.

Figure 1 Redundant designs of catchpits in an overseas city

3 OTHER TYPES OF INLETS

Apart from catchpits, there are two major types of inlets in the stormwater network: (a) "conventional inlets" - the entry points from an open watercourse, either a natural stream or a channel, to a piped network, and (b) from a stormwater network to a treatment pond or treatment device or from a stormwater treatment pond/device to a piped system.

3.1 Inlets - from a watercourse to a pipe

Many of Auckland’s watercourses have been partially piped, resulting in some watercourses being of an open-piped-open-piped nature. This has created a large quantity of “conventional” inlets.

The authors have experienced the following issues in relation to this type of inlet.

3.1.1 Problems associated with an inlet controlled system

When a network’s hydraulic capacity is considered, one needs to consider all components of the system, including the inlets, pipes and outlets. In some cases it appears as if more attention is focused on the design of the pipes, rather than the inlets and outlets.

An example of this is a residential property flooded several years ago in northern Auckland. A watercourse within this section was piped to enable the construction of the house. The calculated 10 year peak flow from its contributing catchment to this section is about 250 l/s. A steep (about 20% in gradient) 225mm pipe was installed and the calculated pipe capacity is similar to the calculated 10 year peak flow. Unfortunately, the house was flooded not long after its completion and the storm was not a 10 year storm. Field investigation showed that the inlet did not have a proper inlet structure, and more importantly, the maximum available water head was only 0.5m before the runoff over topped the inlet “headwall” (It actually does not have a headwall as there is no formal inlet structure). This is significantly less than the required 1.5m water head based on inlet control calculations. Due to lack of a designated overland flow path, the house was flooded. The flooding problem was resolved later at considerable cost by improving the inlet and forming a proper overland flow path.

3.1.2 Inlet blockage with debris

During a heavy storm, particularly when it is associated with strong wind, an inlet can be easily blocked by debris.

Due to safety concerns, some inlets are fitted with safety grilles to prevent children entering the downstream pipes. Blockage of some inlets, particularly those with safety grilles, is another major reason for flooding. Our field observations confirmed that not only are smaller inlets easily blocked, but that even larger inlets can be completely blocked. Figure 2 shows a blocked 1.8 m diameter inlet. Due to the blockage of this inlet the majority of a large recreational reserve was inundated.

Figure 2 A totally blocked 1.8 m diameter inlet and the flooded, large recreational reserve resulting from that blockage (Source: Tian et al, 2013)

3.1.3 Inlet blockage by overgrowing vegetation

Apart from blockage by debris, overgrowing vegetation around an inlet can also block or partially block an inlet. This can easily occur during warm summer as plants grow very fast during such a time.

3.1.4 Safety concerns in relation to an inlet

We often receive requests from local residents for Council to install a safety grille in front of an inlet or reduce the gap between steel bars for an existing safety grille. The safety issue for children, in relation to stormwater inlets is of serious concern to the Council. Unfortunately, it is not a simple issue and there are no black and white answers. A detailed and balanced analysis to resolving this problem may be the best approach. The following factors need to be carefully examined when we consider whether a safety grill should be installed for an inlet, including but not limited to:

- diameter and length of the downstream pipe,
- depth of the inlet,
- steepness of the stream bank upstream the inlet,

- nature of the bank soil,
- inlet location and possible public access, particularly for children,
- whether there is a designated overland flow path downstream of this inlet,
- the possibility of building flooding if the inlet is blocked, and
- nature and area of the upstream catchment.

To address some of the above mentioned problems, practitioners in the stormwater industry should consider the following:

1) The capacity and performance of a stormwater network is subject to the capacity and performance of all components, rather than only the pipes. For some cases, the inlets, outlets, or even manholes can limit the capacity of a stormwater network.

2) A detailed and balanced analysis is required to decide whether a safety grille should be installed at an inlet. When a safety grille has to be installed, one should consider using the grilles which have a lower blockage probability. Other forms of trash racks should also be considered further upstream of the inlet, regardless whether an inlet has or does not have a safety grille.

3) Auckland Council has published a technical report regarding the design, construction, operation and maintenance of inlets and outlets for treatment devices (Morphum Environmental Ltd, 2013).

3.2 Inlets in relation to a stormwater ponds or treatment devices

3.2.1 Inlet - from a pipe network to a stormwater pond or treatment device

The information presented in this section is based on Auckland Council TR2013/018 Hydraulic Energy Management: Inlet and Outlet Design for Treatment Devices (Morphum Environmental Ltd, 2013).

The commonly encountered issues associated with inlets to a stormwater pond or a treatment device include erosion around the inlet, resuspension of settled sediments around the inlet, and safety concerns to pedestrians and vehicles.

If possible, the inlet to a pond or wetland should be submerged to dissipate the energy of the inflow. However, the inlet should be well above the base to minimise the resuspension of settled sediments.

3.2.2 Other mechanisms for introducing stormwater into a treatment device aside from culverts

There are other mechanisms for introducing stormwater into a treatment device aside from culverts. These include:

- Disperse low velocity flow across a landscaped area or through a grassed filter strip.
- Disperse flow through kerb cuts.
- A flow spreading trench around the perimeter of a bioretention area. This could be filled with coarse rock, pea gravel or river stone, or formed as a vegetated blind swale.

The design and location of inlets should consider pedestrian and vehicle traffic safety and comfort. A gutter inlet (e.g. catchpit) may be more efficient than a kerb inlet in capturing gutter flow, but clogging by debris is a problem. However, there are a number of combination gutter inlets that provide some segregation of debris. Information on these types of inlets will be found in transport drainage specifications and through manufacturers.

3.2.3 Booms, Vanes, Baffles, and Anti-Vortex Devices

Other inlet design features that may be considered include various booms, vanes, or baffles. Generally booms and baffles promote uniform flow (reducing areas of high energy flow), while vanes and anti-vortex devices are used to reduce turbulence (which can cause scour).

Floating booms can be used to segregate floating debris and oil for collection and/or to reduce blockage potential.

Although more common for wastewater applications, vanes and baffles can be used to help achieve uniform flow or deliberately separate an inlet from an outlet to prevent short-circuiting. There are two general types of baffles: solid baffles, perpendicular to flow to change flow direction; and perforated baffles, such as gabions or concrete baffles with perforations, which are used to break up a jet flow into a more uniform, lower velocity flow across a larger area.

3.2.4 Level Spreaders

The purpose of level spreaders is to disperse concentrated flows and promote low velocity sheet flow. They are commonly installed:

- upstream of filter strips or riparian buffer areas to help prevent rill erosion or preferential flow paths
- as inlets to rain gardens, ponds, wetlands, sand filters or cartridge filters (downstream of flow splitters)

- to provide dispersed flow from rain tank overflows.

Level spreaders can have several forms including wood or concrete beams, subsoil drain pipes and gravel filled trenches, perforated PVC or PE pipes laid level and parallel with the ground contour), or dispersal bars laid level and parallel with the ground contour but elevated above the surface. These devices serve to spread discharges from a system over a sufficiently large area to avoid concentrated flow.

The key aspect of level spreaders is that they are always absolutely level. Council from time to time receives designs which rely on perforated PVC or PE pipe pegged into the ground (Refer to Figure 3) from new or redevelopment.

Figure 3 PVC pipe dispersal bar with timber supporting structure and outlet holes

The authors have not seen many successful implementations of T-bar disposal. Two key factors associated with this type of level spreader will affect its long tern performance.

A. Whether the perforated pipe can be always level. Some T-bars have never been absolutely level as they were installed without the use of leveling equipment. Where T-Bars are not installed properly, uneven settlement of the supporting structure over time will result in the dispersal bar becoming further out of level.

B. Dispersal bars with smaller holes can be easily blocked. This will result in water flowing out from the remaining clear holes at high velocity, causing land erosion or even stability problems.

A more robust method would be a cast in place concrete level beam where the forms can be properly leveled and a screed used to level the concrete.

Even though level spreaders seek to distribute flow as low velocity sheet flow, downstream erosion protection may still be needed. Figure 4 demonstrates a well designed and constructed level spreader: elevated ends are buried into the banks, appropriate downstream erosion protection is provided and upstream erosion protection prevents undercutting.

Another alternative is incorporating v-notched flow spreader plates, which are less sensitive to minor inconsistencies in level. Typically flow spreader plates, whether v-notched or not, are designed to be adjustable.

3.2.5 Flow Splitters and Diversions

Flow splitters are incorporated into inlet configurations so that flow in excess of the design capacity of a treatment device can be diverted safely away in a controlled manner. They are commonly used for soakage devices and some gross pollutant traps (GPTs), such as centrifugal debris separators, and less commonly used with ponds, wetlands, and rain gardens. Flow splitters can improve treatment efficiency, reduce the likelihood for sediment resuspension (due to high flows), and in some cases reduce the size of the treatment device.

Flow diversions are specifically designed depending on the situation, but often are developed via a weir formed inside a manhole. Weirs can be formed with concrete or by a plate fixed to the concrete manhole. Runoff enters the manhole with the normal discharge to the treatment device on one side of the weir with high flows overtopping the weir and exiting through a secondary outlet. Smooth benching and concrete finishing is important so that turbulence is minimised. It is also important to consider maintenance access and whether the diversion will ‘trap’ debris or become blocked.

Flow splitters are often used to divert large event, high velocity flows away from a treatment device to avoid scour and sediment re-suspension. In this case, the water quality volume or 2-yr ARI flow (for example) is passed through the device with flows in excess being diverted. This is not allowable where the treatment device also provides attenuation.

Figure 4 Well Designed and Constructed Concrete Beam Level Spreader

4 OUTLETS

4.1 Beach outlets

There are thousands of beach outlets in Auckland. The following issues are often encountered in relation to beach outlets.

1) Safety concerns

Generally speaking, beach outlets, particularly those discharging to popular beaches, have significantly higher public access, compared with those outlets discharging to streams. As a result, there is often a requirement to have safety grilles on beach outlets to prevent people from entering the pipeline.

2) Amenity and health risk

Many beach outlets often have groundwater fed base flows, particularly in winter when the groundwater table is high. The constant water flow can wash away the sand in front of the outlet and form a water pond. The ponding water can trap litter or debris and the water can turn brownish or dark in colour. This can be visually unacceptable to some members of the public and in some instances can also be a health risk to the public.

3) Buried with sand

Figure 5 shows a partially blocked 1.5 m diameter beach outlet in northern Auckland area. This photo was taken on 15 March 2014 after Cyclone Lusi passed Auckland. The sand downstream of the outlet was cleared a few days before the Cyclone hit Auckland.

4) Erosion around the outlets

Erosion around the beach outlets often occurs. This either creates a land stability issue, or an amenity problem, similar to as described in 1) and 2) above.

Figure 5 A 1.5 m diameter beach outlet which was blocked by sand and debris after Cyclone Lusi passed Auckland

4.2 Other types of outlets

Apart from beach outlets, there are two other common types of outlets: (1) from a stormwater pond or wetland to a piped network, and (2) “conventional” outlets either from a piped network or from a treatment facility discharging to a stream, a lake or a gully.

4.2.1 Outlets – from Stormwater ponds or treatment devices to a piped network

Outlets should be designed to address all flow conditions, to be safe, and to protect the receiving environment. Low energy discharges can be promoted by outlet design, oversizing the outlet pipe, and reducing head through drop outlets. Providing downstream energy dissipation will be required to compensate for higher velocities and allow for flow transitions from engineering structures to more natural flow regimes.

4.2.1.1 Outlet Flow Management

A large number of outlets are manhole riser outlets that can include low flow orifices and multistage weirs with high flows entering across the entire rim of the manhole. Key design issues include controlling debris, allowing for appropriate access (for maintenance and preventing unauthorised access) and all aspects of health and safety.

As many of these outlets discharge from a stormwater pond to a stream or coastal area, steep outlet pipe grades and the potential for downstream erosion are common. Key design practices should include:

- Try to obtain as much energy dissipation as possible within the service outlet manhole itself. This could include installing baffle blocks or having a sump within the base of the manhole to dampen flow energy.
- Outlets should discharge downstream in the dominant direction of flow in order to avoid erosive turbulence, or ‘waterblasting’ of the opposite bank. The preferred approach is to align the outlet (and channel recovery reach) at no more than a 45° angle to the stream. Where this is not possible, riprap could be placed on the opposite bank to a minimum height of 300 mm above the elevation of the pipe crown, depending on channel width.
- Incorporate flow expansion or channel recovery reaches. As the flow area expands, flow velocity will reduce to maintain continuity.
- Treatment devices (such as ponds, wetlands, online devices, sand filters, etc.) should include a gravity dewatering drain, if possible, to facilitate maintenance activities.

- Consider installing prefabricated polyethylene (PE) bends on small culvert outlets to direct water in the direction of flow.

4.2.1.2 Orifice and Low Flow Outlets

Orifices are a specific type of outlet that convert potential energy (e.g. elevation head) to kinetic energy (velocity) and by their nature have low volume, high velocity flow. Considerations include:

- Generally service outlets should have orifices no smaller than 50 mm to avoid blockage. This requirement can be relaxed for orifices to be no smaller than 30 mm for multiple orifice outlets (e.g. multistage outlets or perforated level spreader pipes, or low flow control on rain tanks).
- Orifices or low flow outlets should be located a minimum of 150 mm from the base of a pond (100 mm above the base of a rain tank) to prevent resuspension of sediment.
- Low flow outlets or orifices are prone to blockage. If the design includes a reverse sloping pipe or a siphon, then water will be withdrawn below the water surface and the outlet will be less prone to blockage by floating debris.
- It is recommended that low flow outlets or orifices be designed to mitigate the adverse temperature effects associated with ponds or unshaded channels. By inclusion of a siphon, baffle plate, or reverse sloping pipe, the outlet can pick up the lower, cooler water than the very uppermost warmest water at the surface that would spill over a weir outlet.
- However, reverse sloping pipes are poor for fish passage. They will be best utilised when there is no upstream habitat, for example when connected to an entirely reticulated system or other offline pond.

4.2.2 "Conventional" outlets from a piped network or a treatment facility discharging to a stream/gully

The issues associated with this type of outlets are similar to beach outlets, such as blockage, amenity, erosion, etc. However, compared with most beach outlets, conventional outlets are normally discharging to steeper gully or stream bank situations. Therefore, energy dispassion is more important.

4.2.2.1 Energy dissipation

While proper siting and design of outlets can reduce the potential for erosion, in many cases formal energy dissipation devices are required if the downstream environs (whether natural stream or treatment device) do not have an adequate ability to withstand erosive forces, or if the forces are significant.

There are many types of energy dissipation devices including flow transitions, riprap aprons, in line outlet weirs and drop structures, concrete aprons with or without baffles, hydraulic jump basins, broken back culverts, etc.

4.2.2.2 Channel Recovery Reaches

Outlets entering natural streams should be set back from the main channel to minimise energy dissipation within the stream itself, minimise effects on opposite banks, and potentially avoid geotechnical issues. Generally a headwall and wingwalls are required, especially if the outlet is recessed into a slope, to prevent slope erosion and facilitate smooth flow transition.

If there is enough room, a longer tributary reach where the stream channel width exceeds pipe diameter can help lower velocities through flow expansion, provide habitat and minimise consenting and requirements associated with works within the watercourse. Rather than piping to the receiving water body, ephemeral stream gullies are ideal for providing setbacks and positions for energy dissipation while retaining the overland flow path (and potentially habitat) function. As a minimum, outlets should be located far enough back to prevent the energy dissipater intruding on the channel.

Channel recovery reaches aim to prevent erosion of receiving environments. In the coastal environment, a conventional set back may not be appropriate, consider locating the outlet away from the active beach system, for example at or near an adjacent headland.

4.2.2.3 Riprap

Riprap is used to provide a hard surface lining that is not subject to erosion as well as providing energy dissipation.

Riprap comes in a variety of rock types and sizes depending on the quarry. It is usually provided (and specified) as a range of sizes such as 400–250 mm where 100% of the material is 250 mm or larger and no material is greater than 400 mm. D_{50}, often used in riprap sizing calculations, is the median diameter of the riprap range. Material larger than about 250 mm is often classified as boulders; however care must be taken, as quarries or providers may define sizing differently.

Angular rock has a much greater angle of repose than rounded rock and should be specified on slopes. Attention to installation of rock, including interlocking of larger boulders, can improve the durability of riprap protection.

The recommended minimum size of riprap is 150 mm. The thickness of the riprap is recommended to be 1.5 to 2 x D_{50}. The thickness should not be less than D_{100} and not less than 300 mm. Riprap should be underlain with geotextile or other filter layers so it doesn't 'sink' into the softer underlying soil and to reduce migration of fine materials from behind the rip rap. Provision of an interlocking layer of smaller 5-50mm rock over the larger diameter rip rap can provide a binding matrix which can re-lock if the larger boulders move, providing a more durable and flexible erosion protection.

However, for natural streams the use of riprap should be minimised to reduce adverse effects (visual, substrate or fish passage, for example).

Figure 6 Hessian Bags filled with Weak Concrete

Riprap may also be grouted in place with a weak sand cement grout (e.g. 7 MPa) which can reduce the size and thickness of riprap needed. However, the use of grouted rock should generally be confined to situations where rock of suitable size is not economic or available or where a smoother surface is

required (for safety or flow efficiency). This is because this type of monolithic structure can be susceptible to undermining or tomos.
Riprap can be quite obtrusive and the visual impacts can be softened through planting. Hessian bags filled with weak concrete mix may also provide architectural alternative to riprap (Figure 6).

4.2.2.4 Aprons

An apron provides an armoured surface to prevent erosion at the transition from a pipe or box culvert outlet to a natural channel. It may be the only energy dissipater or act as additional protection at the exit of other energy dissipation devices. Aprons may also be used to spread the flow of water to sheet flow where no natural receiving water is present.

As discussed previously, reductions in velocity will reduce erosion potential and thus the size of apron needed. Overall, the visual impact of the energy dissipation will decrease. As such, mechanisms to reduce velocity prior to discharge are encouraged, for example rapid expansion into pipes of a larger size, or stilling basin designs.

4.2.2.5 Riprap Aprons

The riprap apron is one of the most commonly used devices for outlet protection, primarily for culverts 1500 mm diameter or smaller, with or without a standard wing wall. Riprap aprons manage the transition from an outlet to the stream channel by increasing roughness and flow width to reduce flow velocity. They are typically less expensive and easier to install than concrete aprons or energy dissipaters. In addition, riprap is flexible and adjusts to settlement; it also serves to trap sediment. Protection is provided by increasing roughness and having sufficient length and flare to dissipate energy by expanding flow area and reducing velocities.

However, if the apron is too short, or otherwise ineffective, it will simply move the location of potential erosion downstream. Riprap aprons should not be used to change the direction of outlet flow and should be constructed, where possible, at zero percent grade for the length of the apron.

An existing outlet with an eroded concrete grouted riprap apron was reinstated using a flexible riprap apron in a central Auckland park (Figure 7). The apron effectively reduced the drop from the wingwall, reduced flow velocity, and provided energy dissipation preventing erosion.

Figure 7 Flexible Riprap Apron for Erosion Protection and Energy Dissipation

4.2.2.6 Concrete Aprons

Concrete aprons with rocks embedded, or constructed baffle blocks (also referred to as impact blocks/columns, Figure 8) provide energy dissipation by effectively breaking up and spreading flow from the outlet.

While riprap is recommended as the preferred option, concrete aprons with rocks or baffle blocks embedded may be used where a large amount of energy needs to be dissipated in a short length as they are relatively short and compact for the amount of energy they dissipate.

Typical baffle block arrangement aligns the first row of blocks so that one block is placed along the centreline of each culvert outlet. Subsequent rows are arranged so that each block is located along the flow path of the jet deflected around the block immediately upstream. Control of bed scour at the downstream end of the outlet structure usually requires the use of additional riprap protection as a transition from the hard concrete to natural channel.

Figure 8 Concrete Aprons with Baffle Blocks Embedded for Energy Dissipation

5 Conclusions

1) The inlets and outlets of a stormwater system, either a reticulation network or a treatment facility, play a vital role for the performance of the system. They can cause capacity, safety, amenity, erosion, efficiency and environmental problems.

2) Unfortunately, these issues have not always received adequate attention from some stormwater practitioners.

3) Some actions or measures to overcome the above mentioned problems are suggested. To avoid these problems, efforts from all practitioners in the entire stormwater industry are required.

6 ACKNOWLEDGEMENTS

This is work in progress and as such no policies have been suggested to/or adopted by Auckland Council.

7 REFERENCES

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