Auckland
Regional Council
TE RAUHĪTANGA TAIAO

Quantification of Catchpit Sediments and Contaminants

Literature Review

October TR 2009/122

Auckland Regional Council
Technical Report No.122 October 2009
ISSN 1179-0504 (Print)
ISSN 1179-0512 (Online)
ISBN 978-1-877540-41-7

Technical Report, first edition.

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Date: 9 March 2010	Date: 26 April 2010

Recommended Citation:

Pennington, S.; Kennedy, P., 2008. Quantification of catchpit sediments and contaminants. Prepared by Golder Associates (NZ) Ltd for Auckland Regional Council. Auckland Regional Council Technical Publication Number 2009/122.

Quantification of Catchpit Sediments and Contaminants. Literature Review

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Prepared for
Auckland Regional Council
Environmental Research

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1 Executive Summary

Catchpits are a key component of the road stormwater system. The sump within the catchpit allows for the collection of debris to prevent potential blockages occurring in the downstream pipes. Although the catchpit functions to collect larger heavier debris, the catchpit also collects variable amounts of finer sediments. As such, catchpits are one of the mechanisms whereby contaminated particulate material from the road, and other sealed catchment surfaces, can be trapped prior to entering the stormwater system and receiving environment.

In New Zealand there is a lack of quantified information on the role that catchpits play in preventing sediments reaching downstream environments. This information is considered critical for determining catchpit efficiencies, for input to contaminant transport models, and for the assessment of an appropriate suite of stormwater treatment methods for a given situation. This report describes a study commissioned by the Auckland Regional Council (ARC) to quantify and evaluate the solids retained by catchpits in the Auckland region. This work includes a literature review and a survey of information held by the local authorities (LAs) in the Auckland region on the quantities of total solids removed by routine catchpit cleaning.

Laboratory studies have shown catchpit sumps to be effective at retaining large objects and sediment particles larger than 500 µm. The inflow velocity was found to have little influence on the retention of these large particulates. However, the retention of the smaller sand and mud-sized particles was shown to be dependent on catchpit design, inflow velocity and the volume of sediment already accumulated in the catchpit.

In the field, catchpits have been shown to typically retain between 30 and 50 per cent total solids. Both field and laboratory studies indicate that higher retention is found during small storm events, which have lower inflow velocities and a smaller volume of stormwater flushing through the catchpit. The particle size of solids retained in catchpits is typically sand and gravel-sized (60 to 90 per cent). While catchpits have been shown to retain a slightly greater proportion of the coarsest fraction measured, two of the field studies showed that the particle size of solids retained in street catchpits is very similar to the particle size of material on roads. This is not what was expected, and not what has been shown in the majority of reviewed laboratory studies where catchpits were shown to typically retain larger particles, in preference for the finer material. At this stage it is uncertain whether there are some mechanisms that could be causing this apparent similarity between particle sizes measured in street dust and in catchpits.

The quality of sediment retained within the catchpits was shown to be similar to that found on roads with respect to metal concentrations. With respect to particle size, trace metal concentrations in the coarser particles in catchpits were typically in the same range as the concentrations measured on the road surface, however higher metal concentrations were found to be associated with the finer particles, possibly due to the more favourable conditions for ion exchange or adsorption within the finer particle structure. Aside from the dissolved fraction, catchpit retention efficiencies for metals will therefore be proportional to how much sediment is trapped in the catchpit, especially the finer sediment fraction.

Catchpits have been shown to have an adverse effect on water quality. This may be caused by the erosion of sediment accumulated within the catchpit, and by sediment and water retained in the catchpit undergoing various chemical and biochemical processes. This poor quality water can then be flushed into the stormwater system and receiving environments during a storm event.

All of the main local authorities in the Auckland region engage contractors to clean roadside catchpits on a routine maintenance cycle (one to five times per year). However, none of the local authorities collect any information about the amount of solids removed from catchpit cleaning. North Shore City Council was the only council that was able to provide an estimate of solids removed per catchpit of 3500 kg per 100 catchpits on average. If it is assumed that this amount is removed on an annual cleaning basis, then this estimate of solids removal can be used to provide a general estimation of the solids removed by each council. As two examples, in North Shore City this would amount to 387,730 kg of solids removed from catchpits per year, and in Auckland City this would equate to 805,000 kg of solids removed from catchpits per year.

2 Introduction

2.1 Overview

Catchpits are installed in most of Auckland's stormwater system to provide a mechanism to minimise blockages in the stormwater system. The sump within the catchpit allows for the collection of debris to prevent potential blockages occurring in the downstream pipes. Although the catchpit functions to collect larger heavier debris that gets through the coarse entry grate, the catchpit also collects variable amounts of finer sediments. As such, catchpits are one of the mechanisms whereby contaminated particulate material from the road, and other sealed catchment surfaces, can be trapped prior to entering the stormwater system and receiving environment.

There has been a range of studies undertaken internationally and in New Zealand on the functioning and performance of catchpits. However, in New Zealand there is still a lack of quantified information on the role that catchpits play in the treatment process preventing sediments reaching downstream environments. This information is considered critical for determining catchpit efficiencies, for input to contaminant transport models, and for the assessment of an appropriate suite of stormwater treatment methods for a given situation.

2.2 Project scope

The Auckland Regional Council (ARC) has identified catchpits as a key component of the road stormwater system. As such, it has commissioned this research to assist it in understanding the role that catchpits play in trapping sediments transported by stormwater.

This report presents the quantity and concentration of total solids, sediments, metals (copper, lead and zinc) and some organic chemicals total petroleum hydrocarbons (TPH)) currently being captured in catchpits in the Auckland region. Key tasks addressed in this assessment are:

- A literature review to examine any work that has quantified solids, the particle size distribution of settled solids, and/or the concentration of contaminants retained by catchpits. The scope specifies that the review also needs to include any information on pre and post catchpit water quality where possible.
- Carry out a survey of any information held by the Local Authorities (LAs) in the Auckland region (Auckland City Council, North Shore City Council, Waitakere City Council and Manukau City Council) to collate and assess any data they may hold on current production of total solids from catchpit cleaning.

2.3 Report contents

This report is set out in two sections following this introduction:

- Section 3 presents a literature review of work that has quantified solids and/or contaminants retained by catchpits, the particle size distribution of settled solids, and information on catchpit water quality.
- Section 4 provides a summary of information collected from the four main LAs in the Auckland region, on the quantity of solids removed from roadside catchpits during routine maintenance in the region.

3 Stage 1: Literature Review

3.1 Approach

In 2003, Kingett Mitchell undertook a literature review that included an evaluation of what was known at that time about the particle size distribution of materials that could be transported by stormwater through catchpits (Kingett Mitchell 2003). That work reviewed published international literature and summarised work undertaken in New Zealand (mainly Auckland), Australia (eg, Melbourne) and elsewhere, on the particle size distribution of particulates on road surfaces. The literature review presented in this report aims to build on this earlier literature review, and in particular to:

- Update the literature review carried out to include any more recent published information.
- Check for unpublished thesis that may not have been captured in the earlier work.
- Identify whether geological and local soil conditions are likely to influence the nature of material entering catchpits from road surfaces.

Kingett Mitchell (2003) also reported on particle size distribution data for urban stormwater. That review discussed the rationale for the change in particle sizes in stormwater between the road surface and the stormwater system. There have been some studies that have sampled at system/catchpit inlets but as reported in Kingett Mitchell (2003) there are very few studies that have reported true, whole stormwater information. This data is much more limited in extent than general stormwater sample data (for quality and particle size).

The following section provides a literature review on studies that have quantified solids, the particle size distribution of settled solids, and/or the concentration of contaminants retained by catchpits. Literature previously compiled and reviewed in Kingett Mitchell (2003) has been reviewed again in light of the ARC study needs.

In the following sections:

- The typical catchpit configuration in Auckland is outlined in Section 3.2.
- Catchpit hydrodynamics and processes affecting sediment retention are discussed in Section 3.3.
- Sediment retention efficiencies are reviewed in Section 3.4.
- The particle size of sediments retained within catchpits and sediment quality are reviewed in Sections 3.5 and 3.6 respectively.
- The effects of catchpits on water quality are discussed in Section 3.8.

3.2 Catchpit configuration

Catchpits (also referred to as catch basins, gully traps or gully pots) are standard features of all urban roads in Auckland. They are devices located at the entry point into the piped stormwater system and are generally covered by a heavy grate that prevents coarse debris such as litter and vegetation from entering the stormwater system and potentially blocking the pipes. The primary function of a catchpit is as noted earlier to prevent blockage (by physically preventing the entry of very large objects into the system) and maintain hydraulic efficiency of the reticulated stormwater system. Catchpit configuration in addition to other factors (discussed later) affect the hydrodynamics within a catchpit and hence their capability to retain particles. Figures 1 and 2 present the dimensions of a standard Auckland City Council (ACC) street catchpit and North Shore City Council (NSCC) street catchpit respectively. Most of the other local authorities in Auckland use a similar catchpit design.

Catchpits typically have a vertical grate entry of 460 x 660 mm, and are located in the gutter of the road (Figure 3). Some catchpits may have a side entry set into the gutter wall. The outlet pipe is located approximately 450 mm above the base of the catchpit, depending on local council requirements, to provide storage for coarse material that has been able to enter the catchpit (through the grate or the side entry slot).

Typically gravels, sands and non-floatable litter that have passed through the inlet grate collect in the sump due to simple gravitational settlement. When working optimally, a layer of water over the accumulated material prevents re-suspension of solids by minimising turbulence and scour from the inflowing water. To function effectively, this accumulated material has to be removed before the storage capacity is lost. Most local authorities have catchpit grate and sump cleaning programmes to attempt to ensure that catchpits function effectively.

Organic material such as leaves, paper, food waste, litter and other organic fragments collected in the sump will start to decompose between storm events. This decomposition consumes oxygen, eventually resulting in production of anaerobic conditions and waters in the sump. These waters mix with fresh stormwater during the next storm event, resulting in a discharge of a “pulse” of poorer quality stormwater to the reticulated stormwater system (typically in the form of a first flush type phenomenon).

Figure 1

Auckland City Council standard street catchpit..

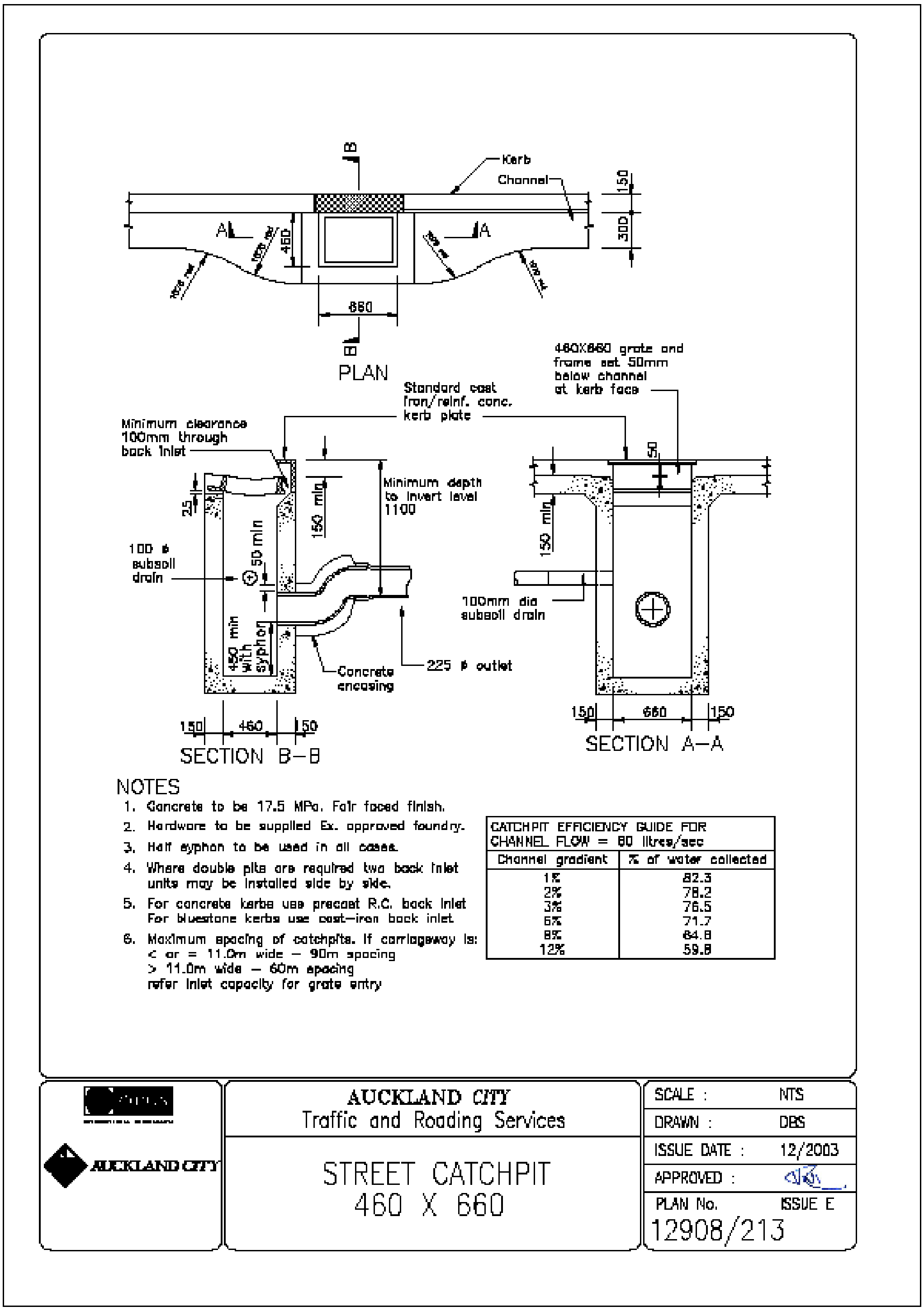


Figure 2

North Shore City Council standard street catchpit..

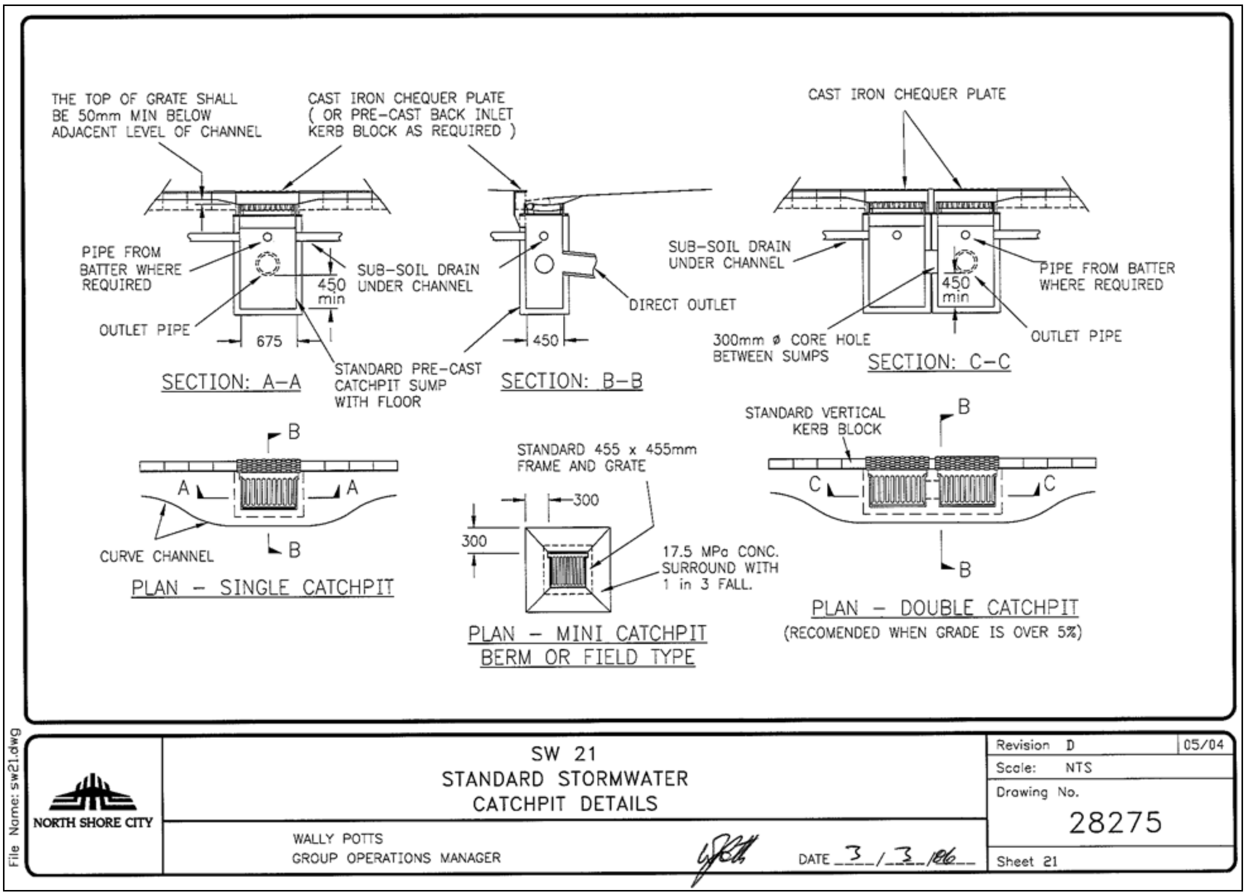


Figure 3

Vertical and side entry catchpits.

3.3 Process affecting catchpit solids retention

3.3.1 Overview

The retention of solids within a catchpit is dependent on the following factors:

- Catchpit design.
- Stormwater inflow velocity.
- Particle size and specific gravity of solids entering the catchpit.
- Accumulated solids from prior events (related to the frequency of sump cleaning).

The effects of these factors on sediment retention have been examined in various experimental studies involving artificial catchpits, and the main findings of these studies are briefly reviewed in the following sections.

3.3.2 Catchpit design and size

Different catchpit designs can increase or reduce solids removal; for example increases in depth from the outlet to the base of the catchpit will increase the cumulative mass of solids removed, as will increasing the area (Memon & Butler 2002a). Lager et al. (1977) described the optimal catchpit design as having a diameter 4 times the diameter of the outlet pipe (D) and a height of 6.5D.

Most catchpits in Auckland use a similar design to the ACC standard catchpit design (see Figure 1). Fassman & Voyde (2007) reported that the standard ACC catchpit has a height of 7D and a length/width of 2D/3D (most catchpits in New Zealand are rectangular rather than cylindrical) and that less sediment is retained with this design, than the optimal design described above.

Orientation of the inlet and outlet pipes has been shown to have an effect on the efficiency with which a catchpit removes solids. For example, Andoh et al. (2007) concluded that catchpits did not remove any sediment at high flows, as all accumulated sediment was washed out; however, this was based on a horizontal inlet at a lower height to the outlet on the opposite side of a cylindrical catchpit, a design completely different to those used in New Zealand. No further studies could be found which specifically highlight the influence of the orientation of the inlet and outlet pipes. This is because most studies examine a typical vertical entry catchpit, with an outlet pipe part way down the side of the catchpit wall.

3.3.3 Stormwater inflow velocity

At low inflow velocities, sediment contained within the run-off is able to settle out within the catchpit sump, however, at high inflows, settlement is not possible, and sediments present in the sump may be exported due to the turbulence created in the catchpit by the incoming stormwater. Hydraulic studies of catchpit inflows in the

United Kingdom noted by Butler & Karunaratne (1995) indicate that inflows to catchpits are typically up to 1 L/s. This flow was calculated to be generated during a 25 mm/hr intensity rainfall event for a catchpit catchment area of about 200 m^2.

The effect of inflow velocity on the retention of solids appears to be related to the particle size of the solids in the catchpit. For example, Butler et al. (2004) used laboratory tests in a catchpit similar to that used in New Zealand, to demonstrate that stormwater inflow flow rate had no effect on the retention of sediments 500 µm or larger using flow rates from 0.5 L/s to 20 L/s; with retention rates of nearly 100 per cent of sediments greater than 500 µm in size. This confirmed earlier work by Lager et al. (1977) using a catchpit of optimal design. Lager et al. (1977) also tested at higher flow rates and demonstrated a reduction in retention of larger particle sizes (840->2000 µm) at high flows of 89 to 178 L/s. While both studies (Lager et al. 1977; Butler et al. 2003) showed that inflow velocity greatly affected retention of smaller particles (100-250 µm), from approximately 60 per cent retained at 7 L/s to ~5 per cent retained at 178 L/s (Lager et al. 1977).

Fassman & Voyde (2007) tested catchpit retention of clay-sized particles (2.5-4 µm) and a mixture of particle sizes (~60-4000 µm) and showed that at 1 L/s TSS concentrations followed the expected pattern, with coarse sediment retained more efficiently than the clay fraction. However, tests at higher flow rates (5 to 20 L/s) gave unexpected results, with the study reporting that the clay fraction was retained more efficiently than the coarse sediment. It is not clear why the results of this study differed from other published literature, however, as discussed in Fassman & Voyde (2007) the clay mixture used in their experiments demonstrated some clumping when added to the influent stream, which may have increased the settling velocity, thus increasing the clay sediment retention efficiencies reported by the authors in this study. At this stage there is no logical reason for the results reported by Fassman & Voyde (2007). As shown in the other studies reviewed (Butler et al. 2004; Lager et al. 1977) it is expected that the coarser sediment would preferentially settle in the catchpit based on the higher theoretical settling velocity of this fraction.

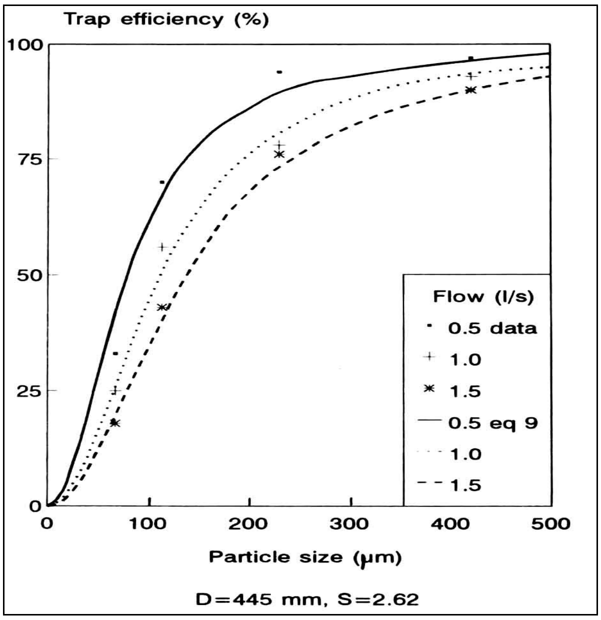
3.3.4 Particle size

Larger particles present in stormwater entering the stormwater system tend to settle out more rapidly and therefore are more effectively removed in a catchpit. Specific gravity (the relative density of an object relative to water) or density (the mass per unit volume) and particle shape influences settleability and therefore retention within the catchpit. Butler et al. (1992) determined the specific gravity of particulate material in stormwater to range from 1.9 to 2.8 (mean 2.4), but without any clear trends with particle size. Chebbo et al. (1990) found that the specific gravity was highest (2.4) in particles 0.1-0.25 mm in size, corresponding to fine to medium sand, and to decline with increasing particle size. Further to the comments made above in relation to specific gravity (or density which are generally interchangeable), it would be expected that the specific gravity or density would vary with particle size especially in sand sized and larger particles. For example, quartz, which is a common mineral in sands, has a density of 2.65 or lower in some morphs of quartz. As heavier elements such as iron, titanium etc. are substituted into mineral structures, the density increases such that minerals such as rutile (TiO_2) which has a density of 4.25 and zircon ($ZrSiO_4$) has a density of 4.6-4.7 (Berry & Mason 1959). In addition, man made materials in stormwater have significant differences in density with extreme examples being low density materials such as rubber and heavy materials such as fragments of iron rust (1-2 mm in size) and magnetic spherules from welding (eg, in the 0.25-0.5 mm size range).

Butler & Karunaratne (1995) examined the removal rates for uniform sized particles in an experimental catchpit (cylindrical, 445 mm diameter and the outlet 400 mm from the base). This study demonstrated 80-90 per cent removal for particles 300-600 µm in size, compared with 15-60 per cent for particles 63-100 µm (Figure 4), confirming that the trapping efficiency of a catchpit reduces with decreasing particle size. The data also illustrates a much broader range in removal rates for the smaller size particles and also with the lowest recorded efficiency measured at the highest tested flow rate (1.5 L/s). As with other work described, the study showed that both particle size and flow rate influence retention and that higher flow rates are more likely to influence the retention rate of smaller particles than larger (denser) particles.

As discussed previously, Butler et al. (2003) used an experimental catchpit of similar design to those used in Auckland and found that almost 100 per cent of particles over 500 µm were removed, while 50-75 per cent of 100-500 µm particles were removed (depending on flow) and only 10-20 per cent of particles 0-100 µm were retained. Sartor & Boyd (1972) showed that virtually all particles >246 µm are trapped in catchpit sumps (medium sand and larger) and that <30 per cent of particles <43 µm were trapped. Another study by Broeker (1984, cited in Butler & Kurunaratne 1995) found that the average trapping efficiency for particles <230 µm in size was 99 per cent. Fassman & Voyde (2007) found that in an experimental catchpit, the coarse fraction demonstrated a greater potential for settling than the finer clay fraction at a flow rate of 1 L/s, this is what we would expect based on other studies. However, they also found that at higher flow rates (5 & 20 L/s) the course fraction exhibited very little settling, while a greater proportion of the fine sediment was retained. This result is reported for completeness although the results reported have not been able to be interpreted in this report.

Figure 4
Measured and predicted catchpit sump retention efficiency (from Butler & Karunaratne 1995) (Note that the lines represent the theoretical predicted removal efficiency, and the points represent the measured removal efficiency).



The particle size of sediments entering catchpits was also reviewed by Butler & Karunaratne (1995) and this indicated that about 50 per cent of particles are less than 500 μm in size. There have been a number of studies describing the particle size distribution of the material on street surfaces in New Zealand. This has been reviewed in Kingett Mitchell (2003). As detailed in Kingett Mitchell (2003) two recent Auckland studies (Ng et al. 2003; Kennedy & Gadd 2002) and a number of other New Zealand and international studies reported in the literature have shown a generally comparable picture of the grain size distribution of material on the road surface. The various studies show consistently that in the absence of adjacent building or site works contributing fine sediments that, transportable/moveable road surface material contains <10 per cent of particles smaller than 63 μm. At the other end of the particle size scale, road surface materials comprise about 30 per cent particles which are >2 mm in size. The proportion is likely to be relatively site specific with the median proportion >2 mm ranging from 9 per cent (Lau & Stenstrom 2001), 17 per cent (Ng et al. 2003), 14 per cent and 30 per cent (Kennedy & Gadd 2002). The reader is referred to Kingett Mitchell (2003) for a more detailed discussion of the particle size distribution of the material on street surfaces.

3.3.5 Frequency of sump cleaning

Depending on the time between emptying a catchpit sump, storm flow entering catchpits can result in the erosion of sediment retained in the catchpit sumps if the flows are high enough. Material in the sump may be removed from the sump by incoming stormwater if the particle size is suitable (ie, it is small enough to be mobilised) and the particles are not armoured within the sump, which increases their resistance to scouring. Morrison et al. (1988) identified that only large storm events scoured out the catchpit sumps. However, changes in the size distribution of the sediment retained, towards a larger particle size, do occur over successive storm events (Memon & Butler 2002a).

Data from Mineart & Singh (2000) of sixty catch basins in Alameda County, California, suggests that increasing the frequency of maintenance can improve the performance of catch basins, particularly in industrial or commercial areas. For example, for catchpits in industrial areas, monthly cleaning increased total annual sediment collected to approximately six times the amount collected by annual cleaning (82 kg. vs 14 kg). These results suggest that, at least for industrial uses, more frequent cleaning of catchpits may improve removal efficiency. However, the cost of increased operation and maintenance costs needs to be weighed against the improved pollutant removal.

Memon & Butler (2002a) also modelled the effect of the frequency of cleaning on the reduction in suspended solids load washed from the road. Changing the frequency from once per year to monthly to weekly changed the per cent retention of suspended solids from 1.8 per cent to 3.7 per cent to 5.2 per cent respectively, when compared to no cleaning. It is not clear from Memon & Butler (2002a) what the rainfall or flow rates were being simulated in the rainfall event. Reference was made to earlier papers (Butler & Memon, 1999); however, it was not possible to determine whether the flow rates referred to in this paper were relevant to the more recent study.

3.4 Solid retention efficiencies

There have been a few studies in New Zealand (Butler et al. 2004; Fassman & Voyde 2007) which have investigated sediment retention efficiencies in constructed catchpits in the laboratory. However, there actually appears to be a limited number of studies examining the removal of sediments in in-situ catchpits, and very few of these studies provide information on solids input, solids output and catchment details. Table 1 provides a summary of published studies which have measured solids retention in catchpits. Where provided, details of the surrounding catchment, the catchpit, the sampling method and the inflow rate have also been included for comparison. The results of each of these studies are discussed further in the following section.

The study by Pitt & Field (1998) examined three stormwater inlet devices; a catchpit sump, fabric filter unit and a coarse filter unit. The catchpit with the sump was the only device that demonstrated significant removal rates for solids, at an average of 32 per cent. A large set of parameters were measured in the sump influent and effluent including metals, however only mean data for the 12 samples was provided in Pitt & Field (1998). Rainfall and stormwater inflows were not recorded during the monitored storm events and the effect of large storm flows on catchpit solids retention was not discussed.

Deletic et al. (2000) collected data from two small road drainage catchments draining to individual catchpits in Dundee, Scotland. Rainfall and flow through the system was measured. Samples were collected by automatic samplers suspended in local manholes in the receiving sewer. Sediment flow into the sumps was not measured, and therefore removal of sediment within the catchpits could not be measured for each storm event. Instead, the mass of sediment and maximum sediment flow rate in the stormwater exiting the catchpit was measured.

In Deletic et al. (2000), TSS output from the Beechwood Terrace catchpit ranged from 0.5 to 226 mg/s, with the lowest mass rate occurring during the event with the lowest run-off volume into the catchpit (52 L). The highest mass rate occurred during the event with a run-off volume of 491 L, which was not the highest volume recorded, but the highest maximum flow was recorded during this event. At the Commercial Street site, the maximum rate and load of sediment leaving the catchpit occurred not during the event with the highest average intensity, but during the event with largest overall run-off volume and longest duration. Minimum sediment export occurred during low intensity, low volume events. This may have been due to either lower rates of sediment entering the catchpit or due to higher retention during these storms. The results indicate that the flow rate into the sump, the duration of an event and the total run-off volume are important factors in sediment export from a catchpit. Overall, solids retention in the two catchpits (based on modelled events) was reported to range from 23.6 – 48.3 per cent.

A range of catchpit insert devices installed in the field were monitored in Michigan and compared to a standard catchpit. This data was summarised in a presentation (DeMaria & Olsztyn 2005), which reported a 10 per cent removal efficiency for a standard catchpit based on the difference between in flowing and out flowing sediment event mean concentrations. The authors also calculated the expected per cent load reduction based on the difference between the sum of the influent and effluent loads. When the sediment load for the input and output was compared, there was no net reduction in sediment due to the catchpit. It is not apparent why there was a difference in the expected pollutant removal efficiency and the load reduction for sediment. However insufficient explanation was provided in this presentation to allow these results to be discussed any further in this report. No information was provided on the range in reductions; inflowing or out-flowing sediment concentrations or loads; or the rainfall or run-off volumes.

A relatively high removal rate for sediment was reported by Aronson et al. (1983, cited in Stormwater Center 2007) of 60 – 97 per cent, however as noted in Stormwater Center (2007) only small storms were monitored in this study. No information was provided on inflowing or out-flowing sediment concentrations or loads; or the rainfall or run-off volumes, and therefore it is difficult to assess the relevance of these results.

Laboratory studies using Auckland City Council design catchpits were conducted by Butler et al. (2004) and advanced by Fassman & Voyde (2007). These used synthetic stormwater samples prepared using a known amount of sediment of a known particle size. Tests were conducted at a range of flow rates that equate to a variety of rainfall intensities. Fassman & Voyde (2007) also report the results of tests with sediment accumulated in the catchpit sump to 25 per cent, 50 per cent and 75 per cent of the storage capacity. These studies found that sediment retention varied considerably with flow rate, as discussed in Section 3.3.3.

Overall the studies reviewed above have shown that catchpits to retain between 0 and 97 per cent of sediment, with typical retentions around 30 - 50 per cent of total solids input. This covers the range of particle sizes that are found on roads and in stormwater. Both field and laboratory studies indicate that higher retention is found during small storm events, which are characterised by lower inflow velocities and a smaller volume of stormwater flushing through the catchpit. Deletic et al. (2000) suggests that sediment retention is a complex interaction of the storm duration, run-off velocity (flow) and run-off volume. However, it was not possible to determine the relative importance of each of these factors based on the information presented.

Table 1
Summary of the studies reporting the retention of solids in catchpits.

Location	Catchment details	Catchpit details	Sampling methods	Inflow rate (L/s)	TSS input (g/m^3)	TSS output (g/m^3)	Solids retention (%)	Reference
Stafford Township, New Jersey	Residential area	Sump depth 914 mm	12 paired samples representing composite inflow and outflow stormwater	NR	75[1]	51[1]	32%[2] (0- 55%)	Pitt & Field (1998)
Scotland	Commercial St, 111 m^2 catchment	Cylindrical 510 mm diameter, height 850 mm	Auto sampler in manhole after catchpit	0.017 – 0.40	Total of 17.4 kg[3]	9 kg	48.3%	Deletic et al. (2000)
Scotland	Beechwood St, 160 m^2 catchment	Cylindrical 510 mm diameter, height 850 mm	Auto sampler in manhole after catchpit	0.042 – 0.41	Total of 8.51 kg[3]	6.5 kg	23.6%	Deletic et al. (2000)
USA, Michigan	15 sites	NR	NR	NR	NR	NR	10%	DeMaria & Olsztyn (2005)
USA	NR	NR	NR	NR	NR	NR	60-97%[4]	Aronson et al. (1983)
Model	NA	Volume = 100 L – 200L; catchpit plan area = 0.159 m^2 – 0.318 m^2	NA	Varies	Varies	Varies	38-58%[5]	Memon & Butler (2002a)
Laboratory	NA	Std ACC design	Sampling every 3 minutes	1	250[6]	105±29 g/m^3	56±11%[7]	Fassman & Voyde (2007)
Laboratory	NA	Std ACC design	Sampling every 3 minutes	5	250[6]	257±124 g/m^3	2±47%[7]	Fassman & Voyde (2007)
Laboratory	NA	Std ACC design	Sampling every 3 minutes	20	250[6]	178± 48 g/m^3	36±17%[7]	Fassman & Voyde (2007)
Laboratory	NA	Std ACC design	Sampling every 3 minutes	4	250[8]	NR	58%	Butler et al. (2004)

Note: NR = not reported, NA = not applicable; [1]Average; [2]% reduction in TSS concentration, average (range); [3]TSS input is modelled based on equations in Deletic et al. (2000); [4]Aronson et al (1983) cited in Stormwater Center (2007), no sampling details were provided so the results are questionable, the original reference was not sourced; [5]The retention efficiency of the catchpit was calculated as the % reduction in TSS load discharged from a catchpit with respect to base-case scenario (ie no catchpit in the system) ; [6]Dry sediment was manually added over the inlet apron at a continuous rate throughout each test period. The target constant inflow concentration was 250 mg/L, while the actual average inflow concentration was verified for each test by before and after test weighing of the vessel containing the dry sediment; [7]Average ± 95% confidence interval calculated using the actual average influent concentration for each test, rather than the target of 250 mg/L; [8]The test procedure involved feeding street sediments to running water, to the catchpit. The street sediments were obtained by vacuuming a number of streets in Mt Roskill within the Oakley Creek catchment.

3.5 Particle size of sediments retained in catchpits

The size of sediment particles retained in catchpits depends on the size of particles entering, the velocities of the incoming stormwater, the total run-off volume and duration, and the frequency of cleaning, as discussed above. A range of studies have measured particle size distributions of sediments collected within catchpit sumps, however no New Zealand field studies were identified in this review. Some of these studies reported particle size information for sediments in catchpits and in the corresponding street surface dusts. Where provided, this information has also been included for comparison.

Duzgoren-Aydin et al. (2006) reported that an average of 90 per cent of solids in all catchpits sampled in Guangzhou, China were sand sized (63 - >600 μm) (Table 2). Mineart & Singh (2000) reported similar results in a study of 60 storm drain inlets in Almeda County, with 80 per cent of all solids in the catchpit sumps found to be sand sized (62 - 2000 μm). However, this study did not report individual data and therefore no summary of this data was able to be provided. Grottker (1990) also found similar results for catchpits in Germany, with approximately 70 per cent of particles 80-1600 μm, with no difference in the particle size distribution between catchpits near to trees and those further away (Table 3).

Table 2
Average particle size distribution of catchpit sump sediments and street surface dusts in Guangzhou, China (all data %, Duzgoren-Aydin et al. 2006).

Particle size	Catchpit sediment[1]	Road dust[2]
>600 μm	21	17
200 - 600 μm	49	48
63 - 200 μm	20	26
2 - 63 μm	9.2	8.1
< 2 μm	0.5	0.7

Note: [1]n = 12; [2]n = 15.

Table 3
Particle size distribution of catchpit sump sediments and street surface dusts in Hildesheim, Germany (all data %, Grottker 1990).

Particle size	Catchpits near trees[1]	Catchpits not near trees[1]	Street dust Hildesheim[2]	Street dust Baden-Wurttemberg[3]
>1600 μm	21.0	21.8	15.9	26.5
1000 – 1600 μm	4.9	5.6	4.9	5.3
500 – 1000 μm	14.7	16.9	18.8	15.3
250 - 500 μm	25.1	23.9	24.1	19.8
160 - 250 μm	14.5	14.3	11.7	13.2
80 - 160 μm	9.3	8.8	7.5	10.0

Particle size	Catchpits near trees[1]	Catchpits not near trees[1]	Street dust Hildesheim[2]	Street dust Baden-Wurttemberg[3]
25 - 80 µm	13.2	8.0	10.9	9.4
<25 µm	1.6	0.5	6.2	0.77

Note: [1]Catchment was residential area, low traffic loading, n = 7 – 8; [2]n = 202; [3]n = 136.

Deletic et al. (2000) found a large difference in median particle size for two catchpit sumps on different streets, measuring a median of 3000 µm at Beechwood Terrace compared to 200 µm at Commercial Street (Table 4). This was shown to be due to differences in the particle sizes in the road dust, which were larger at Beechwood Terrace, due to the poor condition of the road and presence of loose road chip.

As shown in Table 2 and 3, Duzgoren-Aydin et al. (2006) and Grottker (1990) also collected comparative information on the particle size distribution of street surface dusts. Overall, this data shows that the particle size of solids retained in street catchpits is similar to the particle size of material on roads. While results reported by Duzgoren-Aydin et al. (2006) showed that catchpits retained slightly greater proportion of the coarsest fraction measured (>600 µm) 21 per cent as opposed to 17 per cent present in the street dust, overall both the street dusts and catchpit sediments were very similar, mainly (48 and 49 per cent respectively) composed of particle sizes ranging from 200 – 600 µm. However, data from the streets in Hildesheim do show a tendency to contain a slightly higher proportion of small (<25 µm) sized particles (Grottker, 1990) compared to that present in the catchpits.

Table 4

Particle size and distribution of road surface dust and catchpit sump sediments from two streets in Scotland (all data µm, Deletic et al. 2000).

Location	Sample type	d_{10}	d_{50}	d_{90}
Beechwood Terrace	Road surface	2000	8000	10,000
	Gully pot sediment	120	3000	8000
Commercial Street	Road surface	150	1600	10,600
	Gully pot sediment	80	200	4000

Note: Beechwood Terrace was a residential, no exit, asphalt road in poor condition; Commercial Street was an inner city asphalt road, with medium traffic including buses and taxis. d = diameter in µm.

The two papers commented on above have shown that catchpits retain a slightly greater proportion of the coarsest fraction measured, however overall the particle size of solids retained in street catchpits is very similar to the particle size of material on roads. This is not what would have been expected based on the work of Butler et al. (2004) and Lager et al. (1977), which has shown that catchpits retain larger particles (~100 per cent of > 500 µm particles), in preference over the finer material. The question then becomes whether there are some mechanisms that could be causing this apparent similarity between particle sizes measured in street dust and in catchpits.

3.6 Catchment sediment quality

Mineart & Singh (2000) reported information on the quality of sediment samples collected from catchpit sumps in Almeda County. Further data is also reported by WSDE (1995) who presented results for 92 samples collected from a variety of land-uses reported by Serdar (1993) and Herrera (1995). Additional data is presented in WSDE (2001) from several studies of catchpit sediment quality in the USA. Townsend et al. (2002) presents information of catchpit sediment quality collected from 12 locations throughout Florida from January 2001 – March 2002. A total of 67 – 82 samples were collected, mainly from materials emptied from vacuum collection vehicles; but in some cases they were collected from the catchpits themselves. Grottker (1990) reported metal concentrations in samples of three catchpits in Hanover. In addition, some recent data reported by Duzgoren-Aydin et al. (2006) presents information on the quality of 12 sediment samples collected from catchpits in various urban locations in Guangzhou, China. Catchpit sediments were either collected from the catchpit sump or from material removed from the catchpit during routine maintenance. These samples were analysed for a range of parameters. The concentrations of trace metals and TPH reported in these studies are presented in Table 5.

There have been very few studies of catchpit sediment quality in New Zealand. Browne & Peake (2006) recently reported information on the quality of sediment samples collected from catchpit sumps in Dunedin, New Zealand. Composite samples were collected, comprising of sediments from 20 – 30 catchpit sumps spread evenly throughout six areas, covering a range of land uses within Dunedin City. In addition to this data, Table 5 also presents trace element data for sediment samples collected from three catchpit sumps in the main street in downtown Wellington in 1982.

While concentrations of trace metals in catchpit sediments are shown to vary considerably between studies (Table 5), copper, lead and zinc appear to be the key metals of concern, often found at high concentrations in catchpit sediments. This is what would be expected, given the higher concentration of these metals in street dust from the vehicles and road.

Some trends were apparent in the data reviewed, with Mineart & Singh (2000) reporting higher concentrations of trace metals in sediments from commercial and industrial catchments compared to residential. This trend is found in many studies of road dust, gutter dust and stormwater. Duzgoren-Aydin et al. (2006) also reported that higher concentrations were measured in samples from the eastern side of Guanzhou, where a higher proportion of the industrial activity is located. A wide range of concentrations were reported by WSDE (1995), with data coming from a wide range of catchment types.

High organic matter content was measured in the catchpits with nearby vegetation (Grottker 1990) and these sediments also contained lower concentrations of metals in the <1.6 mm particle size class. This is likely to be due to a dilution effect from the organic matter, such as leaves, also found in these catchpit sumps.

The most recent data for copper, lead and zinc concentrations in catchpit sediments in New Zealand (Browne & Peake 2006) appears to be very comparable to concentrations measured in studies overseas (average: 179, 262, 424 mg/kg respectively). That is with the exception of Grottker (1990) that reported much higher concentrations of these metals in the fine sediment (<1.6mm) in Germany. Also concentrations measured in an earlier study of catchpit sediments in Wellington (Kennedy unpublished) are considerably higher than Browne & Peake (2006), however the reason for this difference is not apparent.

The National Institute of Water and Atmospheric Research (NIWA) is currently undertaking a research project on behalf of Land Transport New Zealand (LTNZ), to characterise catchpit sediments in New Zealand. However, the results of this research are not yet available to be included in this review.

A few studies in the USA have measured total petroleum hydrocarbon (TPH) concentrations in the catchpit sediments. Mineart & Singh (2000) report higher concentrations of TPH in residential catchments, compared to commercial and industrial; the opposite trend to that observed for trace metals. Overall, TPH concentrations were shown to be elevated in catchpit sediment; however the concentrations varied considerably between studies.

Pitt (1985; cited in Pitt & Clark 2006) measured the distribution by particle size of contaminants in sediments collected from a stormwater inlet (Table 6). This study showed that higher concentrations of lead and zinc were associated with the smaller sized particles (<250 m). Higher COD concentrations were generally associated with larger particle sizes, possibly due to higher organic matter. TKN and TP appeared to be slightly higher in both the fine particles (<125 m) and larger particles (>1000 m) but lower in the medium and coarse sand-sized fraction.

Some studies provided comparative information on trace metal concentrations measured in catchpit sediment, and in street dusts. Grottker (1990) shows that the trace metal concentrations in the coarser particles in catchpits are typically in the same range as the concentrations measured on the road surface in Germany (Table 7). However, the trace metal concentrations in the smaller sized particles are up to ten times higher in the catchpit; Grottker (1990) reasons that this was most likely due to the more favourable conditions for ion exchange or adsorption within the catchpit.

Browne & Peake (2006) also provided comparative information of trace metal concentrations measured in the suspended sediment from catchpits and street dust in Dunedin, New Zealand (Table 8). Overall the concentrations and relative abundances of the trace metals measured in street dust and sump sediment were very similar (Zn>Pb>Cu).

Table 5
Trace metal concentrations measured in catchpit sump sediments (all data mg/kg).

Location	Cadmium	Copper	Chromium	Nickel	Lead	Zinc	TPH	Reference
USA								Mineart & Singh (2000)
Residential	-	37.9	-	-	43.8	215	5000	-
Commercial	-	56.7	-	-	111	597.5	2050	-
Industrial	-	46.6	-	-	117	307	1950	-
USA	0.5 (0.5-5)	29 (12-730)	25.8 (13-241)	23 (14-41)	80 (4-850)	130 (50-2000)	1036 (123-11049)	Herrara (1995)[1]
USA, Washington	(0.5-2.0)	(18-560)	(19-241)	(33-86)	(24-194)	(90-558)	-	Serdar (1993)[1]
USA, Washington	-	-	-	-	-	-	760 (163-1562)	W & H Pacific (1994)[1]
USA, Portland	-	-	-	-	-	-	208	Breach (pers comm.)[1]
USA, Washington	(<0.22-4.9)	(25-110)	(5.9-71)	(23-51)	(42-640)	(97-580)	-	Thurston County (1993)[1]
USA, Florida	ND	29.4 (5.5-398.4)	17.2 (6.2-50.8)	10 (2.5-30.7)	76.3 (6.4-1060)	153.9 (9.1-956)	-	Townsend et al. (2002)[2]
Germany								Grottker (1990)[3]
Not near trees								
Sediment >1.6 mm	2.04	50.7	10.8	18.1	189	792.7	-	-
Sediment <1.6 mm	22.65	514.6	56.5	123.3	1544	2339.8	-	-
Near trees								
Sediment >1.6 mm	2.28	47.2	10.3	21.5	125	276.7	-	-
Sediment <1.6 mm	6.93	170.1	28.6	49.9	444	895.7	-	-
China, Guangzhou AADT 20,000-70,000	1.0 (0.34-8.13)	105 (24.7 – 206)	54.6 (22.7-742)	23.3 (3.95-345)	189 (70 – 490)	409 (129 – 2640)	-	Duzgoren-Aydin et al. (2006)[4]
Dunedin City	-	179 (145)	-	-	262 (167)	424 (304)	-	Browne & Peake (2006)[5]
Lambton Quay, Wellington	-	402 (266-498)	82 (75-91)	27 (25-29)	2043 (850-4190)[6]	1120 (695-1349)	-	Kennedy, unpublished 1982

Note: [1] Median (range) where appropriate, cited in WSDE (2001); [2] Mean (range), n = 67 – 82; [3]Catchment was residential area, low traffic loading, n = 1; [4]Mean (S.D), n = 6. AADT = Average annual daily traffic volume; [5]Median (range); [6]n=2, samples collected pre-lead removal from petrol.

Table 6
Contaminant distribution by particle size for sediment from a stormwater inlet in Bellevue, WA (all data mg/kg; Pitt 1985; cited in Pitt & Clark 2006).

Particle size (µm)	Lead[1]	Zinc
<63	1200	400
61-125	870	320
125-250	620	200
250-500	560	200
500-1000	540	200
1000-2000	540	230
2000-6350	480	190
>6350	290	150

Note: [1]These lead values are much higher than would be found for current samples due to the removal of lead from petrol.

Table 7
Comparison of trace metal concentrations measured in catchpit sump sediments, and in street dusts in Germany (Grottker 1990).

Parameter	Size fraction	Residential area, few trees[1]	Residential area, many trees[1]	City[1]	Street, Hildesheim[2]	Street, Baden-Wurttemberg[3]
Cadmium	<1.6 mm	22.65	6.93	17.62	3.95	2.58
	>1.6 mm	2.04	2.28	2.97		
Copper	<1.6 mm	514.6	170.1	497.7	76.7	25.1
	>1.6 mm	50.7	47.2	99.5		
Chromium	<1.6 mm	56.5	28.6	66.6	17.0	10.6
	>1.6 mm	10.8	10.3	20.2		
Nickel	<1.6 mm	123.3	49.9	94.3	26.7	20.4
	>1.6 mm	18.1	21.5	29.1		
Lead	<1.6 mm	1544	444	1527	362	84.1
	>1.6 mm	189	125	378		
Zinc	<1.6 mm	2339.8	895.7	2905.7	187.5	152.0
	1.6 mm	792.7	276.7	659.3		

Note: All data mg/kg; [1]n = 1; [2]n = 58; [3]n = 12.

Table 8

Comparison of trace metal concentrations measured in catchpit sump sediments and street dust in Dunedin City (Browne & Peake 2006).

	Street dust[1]	Sump sediment[2]
Copper	129 (79)	179 (145)
Lead	289 (89)	262 (167)
Zinc	528 (206)	424 (304)

Note: All data mg/kg dry weight, standard deviation in parenthesis. [1]n = 3; [2] n = 6.

Based on the literature that has been reviewed in this section, the quality of sediment retained within catchpits appears to be similar to that found on roads with respect to metal concentrations. With respect to particle size, trace metal concentrations in the coarser particles in catchpits are typically in the same range as the concentrations measured on the road surface, however higher metal concentrations are associated with the finer particles, possibly due to the more favourable conditions for ion exchange or adsorption within the finer particle structure. Aside from the dissolved fraction, catchpit retention efficiencies for metals will therefore be proportional to how much sediment is trapped in the catchpit, especially the finer sediment fraction.

3.7 Retention efficiencies

Four studies were identified that reported retention efficiencies for stormwater contaminants (Table 9). Three of the four studies indicate low removal of contaminants, typically 10-25 per cent for COD and trace metals. One study reported reasonable removal of biological oxygen demand (BOD) (Aronson et al. 1983); however this contrasts with most studies of catchpit water quality, as discussed in the following section.

Table 9

Summary of studies reporting retention efficiencies for other contaminants in catchpits.

	Pitt & Field (1998)	Pitt & Shawley (1982)	Aronson et al. (1983)	DeMaria & Olsztyn (2005)
Location	Stafford Township, New Jersey	NR	NR	Michigan
Catchment Details	Residential area	NR	NR	15 sites
Catchpit Details	Sump depth 914 mm	NR	NR	NR
Inflow rate (L/s)	NR	NR	NR	NR
Removal Efficiencies (%)				
COD	11	5-10	10-56	-
BOD	-	-	54-88	-
TKN	-	5-10	-	-
TP	-	5-10	-	-
Copper	-	-	-	9
Lead	-	10-25	-	9
Zinc	-	5-10	-	9
Dissolved metals	-	-	-	7
Bacteria	-	-	-	-12

Note: NR = not reported.

3.8 Catchpit water quality

3.8.1 Processes affecting catchpit discharge quality

The quality of water discharging from a catchpit sump is affected by two main processes:

- Erosion of the sediments contained within the sump, which increases suspended solids and associated contaminants such as COD.
- Discharge of interstitial water from the sediments and overlying water within the sump (sump liquor) of poorer quality than the incoming stormwater.

These two processes are described further in this section.

3.8.1.1 Effects of erosion processes on discharge quality

Fassman & Voyde (2007) found that the incoming flow scoured the surface of sediments within the catchpit sump, resulting in re-suspension of fine sediments and an initial export of water containing high concentrations of suspended solids. However, within a minute of the start of flow, the suspended solids concentration reduced to a consistent concentration, as the water over the sediment bed provides a protective layer. Butler & Memon (1999) confirmed the initial increase in solids in a catchpit discharge, measuring a steady reduction after two minutes; they also noted a similar trend for COD. At high flows, such as 20 L/s, Fassman & Voyde (2007) reported export of sediment from a catchpit when sediment was accumulated to 25 per cent or greater of the maximum possible, however there was negligible export at 1-5 L/s.

3.8.1.2 Effects of sump liquor on discharge quality

Following storm events, organic material such as leaves, paper, food waste, litter and other organic fragments retained in the sump will start to decompose. This decomposition consumes oxygen, typically resulting in the catchpit sump waters eventually becoming anaerobic. This change to anaerobic conditions can result in a number of changes within the catchpit sump waters. These changes include the conversion of oxidised forms of nitrogen to ammoniacal-nitrogen; release of dissolved organic carbon; the dissolution metals from particulates; and in some cases the reduction of some dissolved metals to lower valance states. These processes primarily occur under prolonged dry weather conditions (Memon & Butler 2002b).

Laboratory studies using catchpit sump waters and sediments obtained in the field (Memon & Butler 2002b) have shown initial decreases in COD, followed by an increase in COD after about a week and then stabilisation of concentrations (from 20 to 100 days or more). The initial decrease is due to settling of solids and aerobic stabilisation of organic matter, while the increase occurs from the decomposition of organic matter present in the sediment. In the same study, Memon and Butler (2002b) reported a rapid decrease in dissolved oxygen during the first week of dry weather (eg, from 9 to 2 g/m^3), then concentrations remained stable at around 1-2 g/m^3 in most sumps. In a dry summer period, dissolved oxygen concentrations were reduced to zero within three days (Memon & Butler 2002b). Memon & Butler (2002b) reported a much larger decrease in dissolved oxygen at 20°C (from 5 to 1 g/m^3) than that at 13°C (5 to 3.5 g/m^3). A scum layer on the surface of the catchpit sump liquor resulted in further reductions in dissolved oxygen due to lack of re-aeration (Memon & Butler 2002b).

Ammonium concentrations in sump liquor were typically higher at the end of monitoring than at the beginning; concentrations were also found to be higher in summer samples than in winter samples (Memon & Butler 2002b). Further investigations demonstrated the effect of temperature and the presence of sludge in the catchpit sumps. In the presence of sludge, at 20°C, ammonium increased from an initial 2 g/m^3 to up to 19 g/m^3 after 24 days, while the maximum reached was 8.5 g/m^3 when maintained at 13°C. Without sludge in the catchpit, the maximum ammonium concentration was 5.7-6.5 g/m^3, indicating that the sludge is a major source of ammonium; this is attributed to the decomposition of organic matter (Memon & Butler 2002b).

These laboratory studies demonstrate that the poorest water quality would be found after a prolonged period of warm (~20°C) dry weather. Such periods would be expected to occur in the Auckland region during summer months.

Changes in concentration of dissolved metals would also be expected. The decrease in dissolved oxygen and change to anoxic and reducing conditions results in increases in dissolved metal concentrations in the sump liquor during the dry period (Morrison et al. 1988). However, for most metals, the increase is not constant due to the competing processes of adsorption of metals onto solids as pH increases over this period. Metal concentrations were found to increase to a maximum of 0.013 g/m^3 for cadmium, 0.45 g/m^3 for copper, 0.19 g/m^3 for lead and 0.41 g/m^3 for zinc after an extended dry period (Morrison et al. 1988).

3.8.2 Water quality measured from real catchpits

In contrast to the information gathered in laboratories, there is extremely little published information on the quality of stormwater discharged from a catchpit. This may be related to the difficulty in installing an auto sampler in the field. Table 10 presents a summary of available information on catchpit discharge quality, however, as shown, the parameters measured in these studies were quite limited, and it is difficult to draw much useful information from the reported results.

Table 10
Quality of water discharged from catchpits.

Location	Catchpit details	pH	Conductivity	TSS (g/m^3)	COD (g/m^3)	BOD_5 (g/m^3)	TN (g/m^3)	Reference
London								
Urban commercial	Rectangular, 450x380 mm^2	-	-	10 – 140	170 – 650	-	-	Butler & Memon (1999)
Suburban residential	Rectangular 580x250 mm^2	-	-	40 – 210	50 – 1200	-	-	Butler & Memon (1999)
Rural main road	Cylindrical D = 450 mm	-	-	20 – 240	125 – 400	-	-	Butler & Memon (1999)
Concrete road	Cylindrical D = 450 mm	-	-	5 – 190	50 - 700	-	-	Butler & Memon (1999)
USA	NP	6.94 (6.18-7.98)	364 (9184-1110)	2960 (265-111,000)	900 (120-26.900)	151 (28-1250)	-	Serdar (1993)

Location	Catchpit details	pH	Conductivity	TSS (g/m^3)	COD (g/m^3)	BOD_5 (g/m^3)	TN (g/m^3)	Reference
USA	NP	8 (6.18-11.25)	480 (129-10,100)	-	-	-	-	Herrara (1995)
San Francisco	NP	-	-	-	-	120 (5-1500)	7.0 (0.5 – 33)	Lager et al. (1977)

Note: NP = not provided.

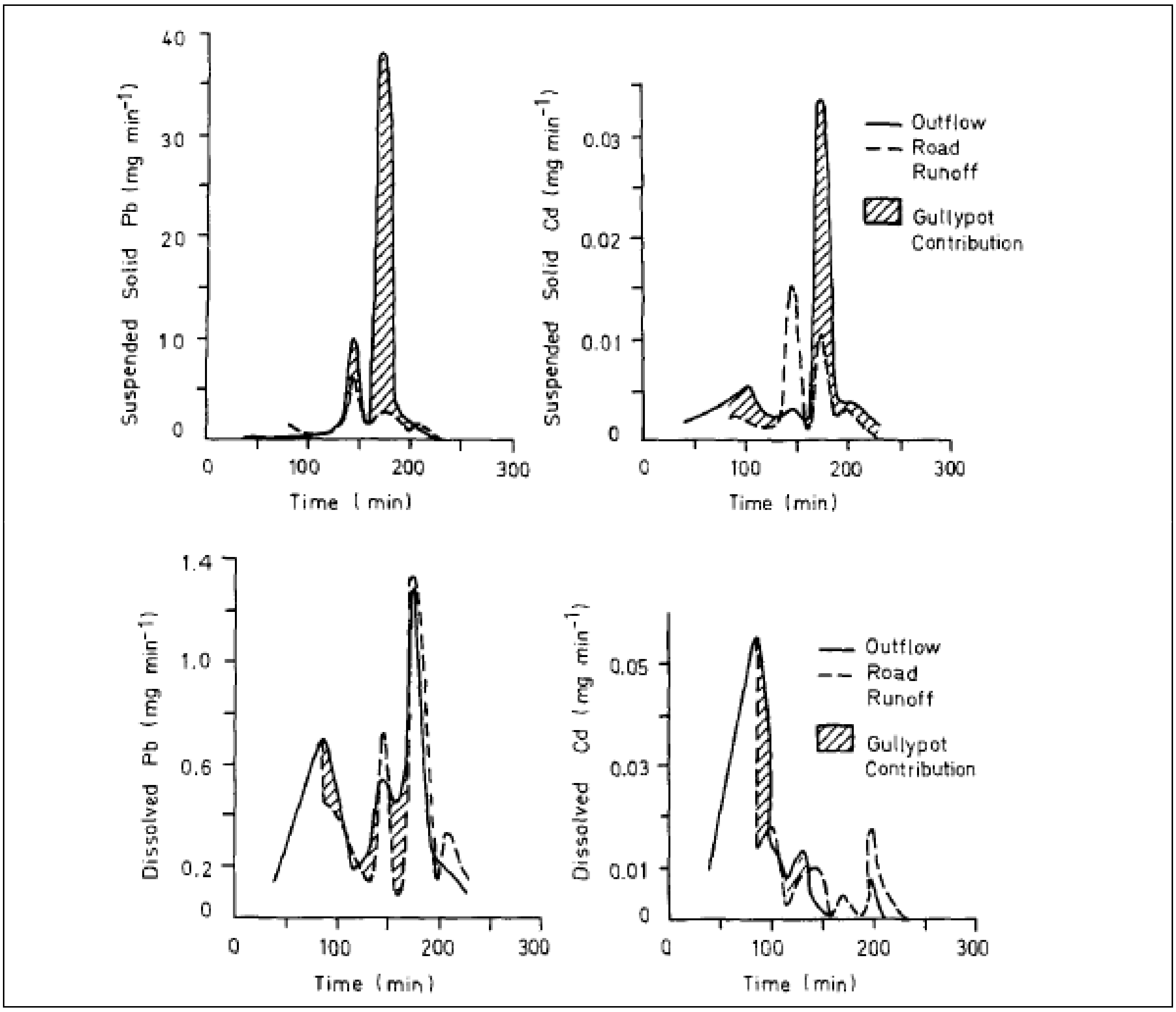
As discussed above, catchpits may be a source of metals to the out flowing stormwater. Morrison et al. (1988) traced the catchpit liquor and interstitial water contributions to metals by comparing the road run-off and catchpit outflow metal loadings. The respective chemographs are shown in Figure 5.

The two upper plots are reported by Morrison et al. (1988) to be typical of all dissolved metals, in that they show substantial early contributions from catchpit liquor and interstitial waters; this is thought to be due to microbial and geochemical degradation processes which act upon the trapped chamber sediments both during and between storm events.

The lower two plots show the suspended solid associated lead and cadmium during a high-flow storm event. The first washout peak of lead associated solids was shown to contribute a relatively small amount of lead compared to road run-off. However, a later secondary peak from catchpit sediment mobilisation releases a much more significant amount of lead to the stormwater system (Morrison et al. 1988). Cadmium shows a slightly different profile, with an early peak, which was thought to be related to highly enriched catchpit liquor suspended solids leaving the catchpit (Morrison et al. 1988). Following this (at around 145 mins) road sediments are deposited into the catchpit, and these are later remobilised and released at 173 min when a peak-flow of 2 L/s enters the gullypot. Morrison et al. (1988) recognises that the contribution of a catchpit to suspended solids loadings in the receiving sewer pipe is highly dependent on the hydrological properties of the storm. During low-flow storm events, catchpits are able to act as small scale detention basins for solids, but these deposits are readily removed by high volume/intensity storms and as a result greatly increased metal loadings are observed in the outflow.

Browne & Peake (2006) collected two samples of suction tanker effluent, after the tanker had collected the liquid and solids retained in the catchpit sumps in Dunedin, New Zealand. The number of catchpits that were represented by each sample is unclear. Browne & Peake (2006) found that suspended solids in tanker effluent from Dunedin contained on average 1188 mg/kg zinc, 262 mg/kg lead and 142 mg/kg copper (zinc>lead>copper in all samples). While the sample may not reflect the exact quality of the stormwater discharged from the catchpit during storm flows (as this will be a combination of the retained water, as well as any incoming stormwater) it does provide some indication of the expected quality, especially relating to metal concentrations. This information is clearly lacking from the international literature that was reviewed.

Figure 5
Metal concentrations in stormwater, indicating the catchpit contribution to stormwater outflows (Morrison et al. 1988).



3.9 Summary

Laboratory studies show that catchpit sumps are effective at retaining large objects and sediment particles larger than 500 µm. The inflow velocity has little influence on the retention of these large particulates. However, particles of this size typically have lower concentrations of contaminants such as metals. The retention of the smaller sand and mud-sized particles is dependent on catchpit design, inflow velocity and the volume of sediment already accumulated in the catchpit.

In the field, catchpits have been shown to typically retain between 30 and 50 per cent total solids. This covers the range of particle sizes that are found on roads and in stormwater. Both field and laboratory studies indicate that higher retention is found during small storm events, which have lower inflow velocities and a smaller volume of stormwater flushing through the catchpit.

The four field studies that were reviewed as part of this work have reported that the particle size of sediment retained in catchpits is typically sand and gravel-sized (60 – 90 per cent). While catchpits have been shown to retain a slightly greater proportion of the coarsest fraction measured, two of the field studies, which compared the particle size of retained sediment to corresponding street sediment, show that the particle size of solids retained in street catchpits is very similar to the particle size of material on roads. This is not what was expected, and not what has been shown in the majority of reviewed laboratory studies where catchpits were shown to typically retain larger particles, in preference for the finer material. At this stage it is uncertain whether there are some mechanisms that could be causing this apparent similarity between particle sizes measured in street dust and in catchpits.

The quality of sediment retained within the catchpits is similar to that found on roads with respect to metal concentrations. With respect to particle size, trace metal concentrations in the coarser particles in catchpits are typically in the same range as the concentrations measured on the road surface, however higher metal concentrations are associated with the finer particles, possibly due to the more favourable conditions for ion exchange or adsorption within the catchpit. Aside from the dissolved fraction, catchpit retention efficiencies for metals will therefore be proportional to how much sediment is trapped in the catchpit, especially the finer sediment fraction.

Very few studies have measured TPH concentrations in catchpit sediments. Overall TPH concentrations were shown to be elevated in catchpit sediment, especially in residential catchments; however the concentrations varied considerably between studies.

Catchpits have been demonstrated in field and laboratory studies to have an adverse effect on water quality. Erosion of sediment accumulated within the catchpit can enrich the out-flowing stormwater, particularly during long duration, high velocity, and high volume storms. During dry weather, sediment and water retained in the catchpit can undergo various chemical and biochemical processes resulting in anoxic conditions, and higher COD, ammonia and dissolved metals than would be found in fresh stormwater. This poor quality water can then be flushed into the stormwater system and receiving environments during a storm event.

While there have been a large number of studies investigating catchpit sediment retention processes, most of these have been laboratory-based. There have been very few studies that have actually measured sediment inputs and outputs in field situations; and fewer still that have also reported information on storm flow velocities, volumes and sediment quality alongside the sediment data. It is presumed that the lack of field studies relates in part to the difficulties associated with sampling from in-situ catchpits.

4 Stage 2: Current Catchpit Sediment Capture

4.1 Approach

All of the main local authorities in the Auckland region engage contractors to clean their roadside catchpits as part of a routine maintenance cycle. The records held by these local authorities were reviewed to provide some rough order information on the amount of material extracted by contractors from the areas maintained. In order to address Stage 2 of the project the following approach was proposed:

- Contact the four main local authorities in Auckland, and collate information on what catchpit cleaning is being carried out.
- Confirm the location and number of catchpits cleaned by each local authority.
- Identify the amount of material removed and on what time cycle.
- Evaluate the information to determine whether the information is sufficiently detailed to allow the calculation of the average catchpit sediment amount removal by area, street or catchpit.
- Identify whether any local authority has collected information on particle size of settled solids or quality data on the material removed.
- Where information is sufficiently detailed, collate information on catchpit or catchpit street aggregate catchment conditions.

Unfortunately, following discussions with each of the local authorities, it was apparent that no information was currently held detailing the quantities of sediment removed from catchpits in the region. However some general information was collected. This information has been summarised and presented in the following section.

4.2 Survey of catchpit cleaning

4.2.1 Auckland City Council

Discussions with Auckland City Council (ACC) staff identified that there are approximately 23,000+ catchpits in Auckland City for road and footpath drainage. Interclean is the contractor responsible for catchpit cleaning in Auckland City. All catchpits are cleaned three times per year, with critical catchpits cleaned five times per year. Auckland City Council catchpit cleaning records indicate if the catchpit is 1/3, 2/3 or full at the time of cleaning, however this approximate estimate would include both the sediment and water retained in each catchpit. Auckland City Council does not collect any specific information about the quantities of solids removed from these catchpits.

During discussions with Auckland City Council, it was apparent that the council is currently having a study of catchpits in Auckland City carried out, which may include some information about the quantities of solids retained by catchpits. However, the results of this study were not available at the time of writing this report and information on completion of this work was not available.

4.2.2 North Shore City Council

Discussions with North Shore City Council (NSCC) staff identified that there are approximately 12,000 roadside catchpits in North Shore City. Catchpit cleaning frequency was related to the road type, with catchpits on local roads being cleaned on a 48-week cycle, while catchpits on HSL roads are being cleaned out on a 28-week cycle. A GIS map reference list was provided detailing the location, and cleanout frequency of all of the catchpits in the area. North Shore City Council does not collect any specific information about the quantities of solids removed from these catchpits. However, Mr Guy Audiss, a Transport Engineer with North Shore City Council, stated that on average 3 to 4 tonnes of silt were removed from 100 catchpits in North Shore City, which equates to approximately 35 kg (wet weight) of solids removed per catchpit per cleaning event on average.

4.2.3 Waitakere City Council

Discussions with Waitakere City Council (WCC) staff identified that there are approximately 12,500 roadside catchpits in Waitakere City. Interclean is the contractor responsible for catchpit cleaning in Waitakere City. All catchpits are cleaned out on an annual basis, but subject to available budget, some cesspits, specifically in the commercial areas and roadside catchpits in the Titirangi/Laingholm/Waima areas, were cleaned out bi-annually. Waitakere City Council does not collect any specific information about the quantities of solids removed from these catchpits.

4.2.4 Manukau City Council

Discussions with Manukau City Council (MCC) staff identified that Opus Consultants manages all of Manukau City Council’s roading contracts, including catchpit cleaning for the City. Opus Consultants advised that Interclean is the sub-contractor responsible for catchpit cleaning in Waitakere City. As for Auckland City, Manukau City catchpit cleaning records indicate if the catchpit is 1/3, 2/3 or full at the time of cleaning, however as discussed this estimate would include both the sediment and water retained in each catchpit. Manukau City Council does not collect any specific information about the quantities of solids removed from these catchpits.

4.2.5 Other investigations

Following the above investigations, it was apparent that none of the local authorities routinely collect information about the quantities of sediment removed from roadside catchpits. However, all of the council's used Interclean as the contractor to clean out their catchpits. Therefore, it was considered appropriate to approach Interclean to see whether they held any information about the quantities of solids removed on a catchpit or area basis, directly, or indirectly through landfill disposal records.

Discussions with Mr Bruce Walton, manager of the Drainage & Road Maintenance Division for Interclean, showed that it was not possible to determine the quantities of solids removed from a catchpit or an area of catchpits based on their current records. This is because of several variables, specifically a truck will be dispatched to clean out an area of catchpits at a time, each truck will therefore contain a combination of solids, and water that has been removed from the catchpit, and Mr Walton said that it is impossible to gauge the solids content of a truck, as it can be highly variable. Following collection, the trucks contents are typically dewatered on their processing site, and then the solids are disposal of to landfill at a later stage. By the time the solids are disposed of to landfill however, the accumulated material is likely to be a combination of several truck loads, from different areas. Therefore, it is not possible to relate the number of catchpits cleaned with the amount of solids disposal of to landfill.

4.3 Summary

All of the local authorities in the Auckland region engage contractors to clean roadside catchpits on a routine maintenance cycle. Catchpits are cleaned out from 1 to 5 times per year. None of the local authorities collect any information about the amount of solids removed from catchpit cleaning. Further discussions with the principal cleaning contractor show that they also do not have any useable information about the quantities of solids removed from catchpits of relevance to this study.

North Shore City Council was the only council that was able to provide an estimate of solids removed per catchpit of 3500 kg per 100 catchpits on average. If it is assumed that this amount is removed on an annual cleaning basis, then this estimate of solids removal can be used to provide a general estimation of the solids removed by each council. As two examples, in North Shore City this would amount to 387,730 kg of solids removed from catchpits per year, and in Auckland City this would equate to 805,000 kg of solids removed from catchpits per year. However, it must be noted that most councils reported cleaning some catchpits on a more regular basis, and therefore these numbers are likely to underestimate the overall quantities of solids removed.

The lack of information available on the quantities of solids removed from catchpits in Auckland was not anticipated. As discussed above it may be difficult to determine the quantities of solids, because of the uncertain amount of water removed at the same time from each catchpit.

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