PARKING LOT TYPICAL STORMWATER RUNOFF CONSTITUENTS AND STORMWATER HARVESTING

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Supervisor: Dr. Isobel Brink **April 2019**

Declaration

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Abstract

The purpose of this research is to establish whether stormwater runoff constituents can be linked to a specific land use. Comparing local runoff constituents gathered throughout the study with international published values, specifically the BMP database. Based on the information obtained during the research period, a preliminary design for a stormwater harvesting system is proposed. This was also inspired by the major drought in Cape Town at that time. During the study gaps within the stormwater management in South Africa were identified. There were definite comparable results between the samples that were tested and BMP database. With enough information sustainable drainage systems can be adapted and implemented to most new developments.

Opsomming

Die doel van hierdie navorsing is om vas te stel of stormwaterafloop besoedel komponente gekoppel kan word aan 'n spesifieke grondgebruik. Die plaaslike afloop besoedel komponenete, wat deur die studie versamel is, is met internasionale gepubliseerde waardes vergelyk, spesifiek die BMP-databasis. Op grond van die inligting wat gedurende die navorsingsperiode verkry is, word 'n voorlopige ontwerp vir 'n stormwater opvangstelsel voorgestel. Dit was ook geïnspireer deur die groot droogte in Kaapstad tydens die studie. Tydens die studie is gapings in stormwaterbestuur in Suid-Afrika geïdentifiseer. Daar was definitiewe vergelykende resultate tussen die monsters wat getoets is en BMP databasis. Met genoeg inligting kan volhoubare dreineringstelsels aangepas en geïmplementeer word vir die meeste nuwe ontwikkelings.

Acknowledgments

Throughout the project my world has changed, I was captivated with the topic of stormwater management in a holistic manner. Saving the environment became my mission in life, and this research project provided me with the building blocks to follow my goals in life.

I am especially thankful to my farther, who gave me the opportunity to grow into the person I am today, and his undying support in this research project.

My supervisor I am very thankful for giving me this project and supporting my passions, where she gave me the freelance to create my own project, and support and guidance whenever I needed it.

I would also like to thank the staff in the water laboratory for helping me with my practical research.

I am also thankful for my friends. Their love and support during the two-year period will always be remembered.

For my colleagues showing me the world of water and environmental management in South Africa and around the world.

Contents

List of Acronyms

As Arsenic

AT Alternative Technology

BMP Best Management Practices

CAF Central Analytical Facility

Cd Cadmium

Cu Copper

EMC Event Mean Concentration

ISS Inorganic Particulate Solids

IUWM Intergraded Urban Water Management

GI Green Infrastructure

LID Low Impact Development

LIUDD Low Impact Urban Drainage Design

Pb Lead

SANS South African National Standards

SuDS Sustainable Drainage Systems

TSS Total Suspended Solids

USEPA United States Environmental Protection Agency

WSUD Water Sensitive Urban Design

VSS Volatile Suspended Solids

Zn Zinc

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Chapter 1 Introduction

1.1 Purpose of study

The primary purpose of this research was to establish whether stormwater runoff constituents can be linked to a specific land use, specifically parking lots, through comparing local runoff constituent to data obtained from international case studies (BMP Database, 2016).

The secondary purpose of the study was to prepare a preliminary design for a stormwater harvesting system at the study site partially based on the information obtained above.

1.2 Background and Motivation

Internationally, stormwater quality is currently seen as the leading remaining cause of poor water quality in natural water systems (US Environmental Protection Agency, 2016). Stormwater quality management is a major problem in South Africa. Johannesburg, Cape Town and Tshwane metropoles noted in their State of the Environment Report (SOER) that untreated stormwater is one of the main contributors to poor water quality in South Africa (Fisher-Jeffes & Armitage, 2012).

The declining quality of surface water globally is primarily the result of the exponential growth of world populations, industrial and agricultural activities and climate change; threatening to alter the natural hydrological cycle (United Nations, 2014) . Although attention has been given to this topic since the 1960's, research and innovation in in stormwater runoff quality, a main contributor to poor surface water quality, has slowed down. Only a few designs are based on quantitative theoretical bases, instead, prescriptive methods have mainly been used (Brink, 2016).

Determination of stormwater runoff constituents is a major requirement when developing design methodologies for water quality control structures in urban areas. Due to a general lack of stormwater quality data, guesswork is required for sites yet undeveloped; and field studies with intensive time and financial input requirements are needed in developed sites. Therefore, difficulties and costs associated with obtaining data has resulted in the neglect of stormwater quality considerations in our urban environments.

The science of stormwater quality must be developed from a valid foundation if the technologies of stormwater quality structures are to grow. This must include valid and usable stormwater constituent data. The University of Cape Town (UCT) recently developed a guideline document; "The South African Guidelines for Sustainable Drainage Systems", which contributes to the improvement of designing of stormwater systems (Armitage *et al*., 2013). The document is a good basis for stormwater management but must still be tested through application to confirm its effectiveness in the South African climate, biodiversity and social diversity. This document was used for the preliminary design of the bio-retention garden, as well as supporting manuals from different sources.

1.3 Problem Statement

Stormwater constituent data is difficult to obtain for use in stormwater control structure design. Greenfields sites have no post-development runoff data and existing site data collection is time consuming and expensive. Therefore, design engineers are at times expected to design stormwater quality control structures without valid or representative data. It is theorised that the growth in stormwater control structure technologies has stagnated due to this. Therefore, stormwater quality is currently neglected in new developments and few new innovations in control structure design with sound scientific bases have emerged.

With evidence of global climatic threats, i.e. dry areas becoming dryer and wet areas becoming wetter, stormwater management has become an increasing priority for urban areas. Cape Town's "day zero" is a possible example of drastic global change and alternative water sources must be investigated. It is put forward here that stormwater harvesting is a viable technology for water reuse and subsequent water savings during drought.

1.4 Assumptions

Land-use categories were limited to those on which data is adequately available within the International Stormwater BMP database (BMP Database, 2016) . Many different land-uses exist. Simplification was however required to create large enough data groups for statistical analysis.

The main assumption during the research period was that the site can be compared with stormwater concentrations from land uses such as business and educational buildings in the International Stormwater BMP database. Additionally, it was assumed that the runoff constituent concentrations from the BMP database are based on the similar rainfall conditions. Further studies would need to be conducted to confirm this assumption.

The intervals between samples varied for each storm event, due to rainfall being unpredictable, but perhaps more so because of the drought. Rain would typically fall for a few hours, then stop for a few and start again. This provided interesting data and indicated the viability of first flush phenomenon. First flush phenomenon is when the pollutant concentrations in stormwater is higher at the beginning of the storm event and reduces throughout duration of the storm (Stenstrom &

Kayhanian, 2005). This phenomenon was found to be dependent on the rainfall patterns during the research period. If a scattered rainfall pattern was present, the phenomenon tends to be non-viable. But with a consistent rainfall pattern throughout the storm, it was observed that the phenomenon is as predicted.

1.5 Limitations

The main constraint for the study was time. The student had to wait for rain before any data could be collected. With the Western Cape undergoing a major drought during 2017 it took quite a few months before sufficient stormwater could be collected for testing.

Although stormwater contains many pollutants that is of concern to human health or the environment, this research covered particulate solids and metals data only. This was primarily due to time and funding limitations. Testing for TSS, VSS and ISS was time consuming; after tests were conducted the data for the first few samples were insufficient. The samples could not be retested due to running out of time where the stormwater would still provide viable results.

Finally, due to working with such small concentrations of constituents, measuring mistakes could have occurred during analyses in the laboratories.

1.6 Chapter overview

The following chapters were included:

Chapter 2 provides a broad overview of different stormwater management principles, internationally and in South Africa. The chapter also provides a literature review of design principles regarding stormwater quality control and harvesting research literature.

Chapter 3 provides detail on the methods used to obtain the stormwater samples, how the samples were tested in the laboratory and how international data was processed for comparison with on-site data.

Chapter 4 provides the results of the tests conducted in the two laboratories, as well as the assessment, understanding and breakdown of the findings / results interpretation and documentation.

Chapter 5 provides a preliminary design for stormwater harvesting at the study site with a sustainable quality control system.

Chapter 6 Summarises the findings and conclusions of the study / research. It also provides recommendations for future studies.

Appendices provide documents supporting the research conducted, such as raw data, calculations and drawings and supporting documentation.

Chapter 2 Literature Review

2.1 Introduction

Stormwater is defined as water that runs from, *inter alia,* rooftops, streets, parking lots, yards, sidewalks and fields after a rainfall event (Michigan State University, 2017). The polluted stormwater runoff from different urban areas varies in terms of pollutant type, pollutant concentration, runoff volume and hydrological aspects. These characteristics should be included when designing for sustainable urban drainage, which not only reduces the flood risks but also the pollution that end up in our streams, rivers and the sea.

Stormwater drainage systems consist of storm drains, catch basins, pipes and outfalls that are designed to carry water away from urban areas, mainly for the prevention of flooding (Michigan State University, 2017) . Therefore, engineering design for stormwater systems primarily tends to consider getting the water away from urban areas as quickly as possible without treating the water before it enters the environment. In South Africa a dual drainage system is commonly used, one for stormwater and one for wastewater, whereby stormwater is diverted not to treatment plants, but directly to streams and rivers. Such stormwater can carry many pollutants that may have detrimental effects on the health of the fauna and flora surrounding a natural water body (Carson, et al., 2014).

The impacts of urbanisation have caused natural systems to fail. Hydrological changes have been made that caused general increase in impervious coverage and the canalisation of watercourses, which all contributed to these failures. For example, with the construction of roads median islands are constructed to alleviate the increase in flow. These islands have replaced natural draining soils containing old roots, voids, animal borrows and root channels, which all provides the soil with a natural capacity to absorb stormwater. Even though, during construction, the topsoil is removed to be returned to the islands with vegetation after construction, the disturbance of the soil changes the natural structure, which reduces the permeability of the soil.

The reduction in surface area vegetation coverage and encroachment into floodway and water courses increases the flow of runoff. There is also a decrease in the infiltration from permeable areas, as these areas are now smaller and become saturated faster. Additionally, construction sites increase sediment runoff and deposition. Studies have shown that up to 100 times more sediment runoff is accumulated from construction sites than from natural catchment areas. Therefore, construction sites have unique problems in terms of stormwater. This contributes to the structural deterioration of water courses, including biological and aesthetic water qualities, with an increase in debris load, and a reduction of groundwater recharge (Brooker, 2015).

Therefore, there is much to learn from stormwater management by using a more holistic approach to improve the quality of surface water and reducing flood risks. Global warming, climate change and increasing urbanisation is causing a detrimental effect on aquatic life and potable water demand, good stormwater management practices can alleviate these problems.

2.2 Stormwater Management in South Africa

2.2.1 Introduction

Recently, stormwater management has become a topic of discussion in South Africa. The University of Cape Town conducted an in-depth review of most international practices and studies related to stormwater management. These included a study of SuDS (Sustainable urban Drainage Systems), used in Australia and European countries, as well as Best Management Practices (BMP), used in the United States. All the relevant information collated by them was used to compile a South African SuDS Guideline. However, because there is currently not enough South African data on climate, pollution concentration and composition of stormwater, as well as on maintenance or technical designs of systems, the manual can currently only be used as a guideline. Furthermore, from the international guidelines, it has been found that there is no exact science for stormwater management systems, and each site should be designed to its specific characteristics. (Armitage, et al., 2013)

The main reason for the failure of stormwater management is lack of funding. The funding is generally provided through municipal rates for water and electricity. Due to other needs, stormwater funding sometimes is only a 10th of what is needed for management purposes. When designing stormwater systems, currently the main concern is designing for runoff water, for flooding, where there is not enough data or funding available for the quality management of the water (Fisher-Jeffes & Armitage, 2012).

A possible way to improve attention given towards the inclusion of quality of stormwater in designs would be for municipalities to start charging levies / taxes for management of stormwater for implementation of Sustainable Drainage Systems (SuDS), where stormwater is treated as close to the source as possible (Fisher-Jeffes & Armitage, 2012) . Specifically, allocated funds to manage stormwater, a disaster must take place before funding is made available (Nell, 2017). From a report "*Charging for stormwater in South Africa*", it was found that the estimated amount residents will have to pay for maintaining stormwater systems will be approximately between ZAR 30 to ZAR 110 per residential unit per month (Fisher-Jeffes & Armitage, 2012). In-directly, in this instance, the "polluter should pay" principle applies:

"The 'polluters pays' principle is the commonly accepted practice that those who produce pollution should bear the costs of managing it to prevent damage to human health or the environment." (Clark, 2012)

There are many factors to consider when implementing water management systems, such as: local hydrological cycle, climate, different ground and geological conditions (Armitage, et al., 2013). The focus on stormwater quantity while neglecting quality is likely because until recently, overall responsibility of stormwater management in South Africa was the responsibility of the Department of Transport where the main concerns of road engineers are to get the water off the road as quickly and effectively as possible. In recent years this responsibility was moved to the Department of Water & Sanitation. This Department would hopefully add emphasis to the quality of stormwater in future (Nell, 2017). Although not the constitutional body, Department of Environmental Affairs has funds available for research projects regarding stormwater.

The advantages of improved stormwater runoff quality are a reduction in the transport of diseases, saving cost of purifying potable water and increased protection of natural eco-systems (Schoeman, et al., 2001). South Africa, with its wide range of diversity in urban areas (high-density low-income areas, low-density high-income areas, and middle class) can be a valuable site for testing various SuDS systems for developing countries. Important aspect as both Australia and USA are developed countries. Therefore, international guidelines have the potential of application towards the inclusion of indigenous plant species and other local considerations.

The general focus points for SuDS design principles include a consideration of the quantity, quality, as well as amenity (desirable or useful feature or facility of a building or place) and biodiversity impacts (Armitage, et al., 2013). For example, concrete lined channels increase flood peak flows, in a controlled manner, but can also increase the chances of erosion and further sediment pollution if not constructed, maintained and monitored correctly (Brooker, 2015). Therefore, when constructing concrete linings, care should be taken to ensure that proper maintenance and monitor plans are implemented for local considerations (Brooker, 2015). When using concrete lined channels; pollution is not absorbed by the soil and is transported to the sea without any filtration process, taking along diseases, bacteria and pollutants that could have been mitigated through filtration into vegetated soil that absorbs pollutants.

There are various control measures for each focus point highlighted and recommended by the South African Guidelines for Sustainable Drainage Systems:

- For the quantity of run-off water to be mitigated, rainwater harvesting, infiltration, detention, conveyance, long-term storage, and extended attenuation storage are suggested.
- To improve the quality of the stormwater, various tools are available for any type of project, these are: Filtration and bio-filtration, adsorption, biodegradation, volatilisation, precipitation, plant-uptake, nitrification and photosynthesis.
- Amenity management is to provide desirable features to a project, to make it socially acceptable and aesthetically pleasing, these measures can include: Health and Safety, Environmental risk assessment and management, recreation and aesthetics, education and awareness
- The last focus point, biodiversity management, includes the protection of species, maintenance of habitats effected, and enough monitoring

(Armitage, et al., 2013).

Furthermore, with the increase in droughts and population, stormwater harvesting should also be investigated as part of solutions in stormwater management. Increase in point and diffuse pollution sources, failure of wastewater drainage systems, and poor to non-existent sanitary facilities, affects the quality of natural waterways (Brooker, 2015).

2.2.2 Legislation and Guidelines for Stormwater in South Africa

South Africa's legislation regarding stormwater management and construction of drainage systems comes from various sources. The "Red Book", which is used as a guideline for the planning and design of human settlements provides three general rules when designing drainage systems. The first is the "common enemy" concept, which means that everyone has the right to alleviate the impact of stormwater on their property through diversion or retention in their own manner. The second is the natural flow of the stormwater may not be obstructed so that it dams up in the higher property or accelerate the flow which will overload the watercourse and cause excessive damage. The third is the reasonable-use rule, where each landowner has the right to use their property as they see fit, but should not be harmful to others, if so, the landowner holds responsibility. The local authority has the right to change natural drainage for the benefit of the public, such as streets and drains, which will influence the quality, quantity and velocity of the stormwater (CSIR Boutek, 2000).

Clause 19 of the National Water Act, Act No 36 of 1998 discusses the prevention and remediation effects of pollution. Alleviating pollution of water sources is the responsibility of the land owner who must control and prevent any such pollution by implementing measures on their own costs. If the responsible person does not follow reasonable action the local authority may act by providing a date whereby the actions should be completed. If the responsible person does not act by the given date, the authority may take their own action in remedying the problem and recover all costs from the responsible person(s).

Other national legislation that can be influenced by stormwater management are:

- National Building Regulations & Building Standards Act, 1997 (Act 103 of 1977)
- Conservation of Agricultural Resources Act (Act 43 of 1983)
- National Environmental Management Act (Act 107 of 1998)
- Disaster Management Act (Act 57 of 2002)
- National Environmental Management: Biodiversity Act (Act 10 of 2004)
- National Environmental Management: Waste Act 59 of 2008

Provincial legislation considered for stormwater management in South Africa is:

- Western Cape Planning Development Act (Act 7 of 1999)
- Land Use Planning Ordinance, 1985

Safety standards for managing stormwater in South Africa focus on ensuring that the velocity and depth of flow is monitored, where the energy head should be not higher than 0.5 metres. Energy head is a way to express energy in hydraulic terminology, e.g. potential energy head = E/(m*g) (Verterra, 2018).

The City of Cape Town (CoCT) provided an integrated Development Plan for the Roads and Stormwater Department (Roads & Stormwater Department, 2009), where the main objectives of the plan were to:

"Reduce the impact of flooding on community livelihoods and regional economies. Safeguard human health, protect natural aquatic environments, and improve and maintain recreational water quality (Roads & Stormwater Department, 2009) *."* Suggest that it is clearly distinguished between the

flooding (flood hydrology) and pollution (environment/utilization hydrology) concerns related to stormwater.

This was set out in a policy generated by the CoCT, policy number C58/05/09, approved by the Council on 27 May 2009. It showed the city is slowly moving in the right direction, however SuDS is not legislated yet.

For construction projects the local authority's main objective is to ensure the flow rate of stormwater before construction is the same as after construction. Other objectives that are taken into account by the authorities is to control the runoff volume, maintain natural groundwater flow, maintain or even improve runoff water quality, provide space for riparian corridors, visually and structurally integrate into the built natural environment and implement SuDS at appropriate scales. (Roads & Stormwater Department, 2009)

Although, all the laws are set out by the Department of Roads and Stormwater the implementation and monitoring of these laws is lacking. SuDS still needs to be fully developed to be implemented in the laws and regulations of stormwater management. Some of the principles can be used throughout the country, for the technology is easy to understand and implement.

2.2.3 South African SuDS Case Studies

The following case studies shows how SuDS principles have been implemented in South Africa.

a) The Cape Town Grand Parade

A permeable pavement area in the Western Cape was designed for the 2010 Federation of International Football Associations (FIFA) world cup, to reduce the impact of flooding on the Cape Town Grand Parade (UCT Urban Water Management, n.d.) . The Grand Parade is situated in the middle of the city. Permeable concrete blocks were used, which reduces stormwater sheet flow and the pavement voids also helps the soil respirate through thermal action, supplying oxygen to the roots of plants and assist aerobic bacteria growth (Vanstone Precast (Pty) Ltd, n.d.).

Figure 2- 1: Cape Town Grand Parade and old city hall (Wikipedia, 2016)

Upon visual inspection the area seems well maintained and cleaned regularly with no visible clogging of the pavement. The area is mainly used for parking and a few local stalls, selling clothing and African artwork. The permeable pavement is still working after 8 years of being constructed, but it cannot be predicted how long the pavement would continue to work over a longer period.

b) University of Witwatersrand parking area

In 2007 the University of Witwatersrand reconstructed an underused sports field into a permeable parking lot, due to an increase in student parking needs (Water Research Commission, n.d.). It has an area of 13000m^2, it is currently one of the largest permeable carparks in South Africa and is used to attenuate excessive flooding of Empire road (Leisure, outdoor & landscaping, 2009). The parking lot also provides environmental benefits of filtering out pollutants, and storing the stormwater for reuse, by recharging the water table (Leisure, outdoor & landscaping, 2009).

Although, permeable pavements show improvement of surface water quality, attention to filtration and clogging research is still needed (J.Sansalone, et al., 2012). Maintenance such as vacuuming, and sonication is needed to keep the pavement from clogging (J.Sansalone, et al., 2012). Sonication is the use of sound waves to break different clogging particles apart (Gillespie, 2018). These maintenance measures are expensive and time consuming, therefore not feasible in developing countries like South Africa.

c) Century City Wetlands

Century City, situated outside of Cape Town City Centre, has wetlands that consists out of four ponds. Stormwater from the house roofs, roads and parking lots drains into these ponds to be cleaned, where each pond has a different function. The first two ponds are used for reducing the flow rate and allow particulate particles and phosphates to settle out in the ponds. The third pond is used for aeration of the water; the pond is large area with deep open water, where the bacteria in the water can break down into nitrogenous compounds. The last pond is shallow and well aerated as well as densely vegetated; the vegetation helps with the reduction of residual nitrates and phosphates. Figure 2-2 shows one of the ponds, as can be seen, the area is well maintained, with the canals used for recreational purposes, as well as a habitat for birds (Matthews, 2010).

Figure 2- 2: Century City Canal connected to constructed wetlands (UCT Urban Water Management, n.d.)

d) Monwabisi, Cape Town

Monwabisi is an informal settlement situated in the Cape Peninsula district, which has been plagued with problems (extensive flooding) during storm events. A group of students from Worcester Polytechnic Institute took part in an Interactive Qualifying Project, where they generated a pilot project to implement SuDS. The two main objectives of this study were to reduce the impact of flooding and implementing systems for low lying areas where water tends to pool and stagnate, causing diseases and groundwater pollution. (Button, et al., n.d.).

Monwabisi has no formal stormwater management systems in place and some of the residents took it upon themselves to implement systems to reduce the risk of flooding, but this did not go down well with neighbours, whose gardens and homes were flooded by the diversions (Button, et al., n.d.). The students used the main road as the test site, implementing systems such as swales, soakaways, infiltration trenches and wetlands (Button, et al., n.d.).

Currently the area is still undergoing major flooding, with many residences waking up in flooded homes. Almost 2 000 informal homes around the area are affected by flooding after heavy rainfalls, leaving up to 25 000 people in danger of losing their homes (Palm, 2018).

Informal settlement projects must have community involvement for any success in the project. Community involvement will ensure that the monitoring and management of the systems will be easier to implement. The students therefore generated a guidebook on when and where the systems can be implemented, monitored and managed. A brochure was also compiled for the residents to explain how they will be affected by the new developments. (Button, et al., n.d.).

2.2.4 Different stormwater control systems

The treatment/control of stormwater can be defined in four different categories or a combination of these categories (Armitage, et al., 2013) . These categories are: 1. Good housekeeping, 2. Source Control, 3. Local Control, and 4. Regional Control. These are further discussed below:

a) Good housekeeping

Prevention by individuals has the potential for the greatest reduction in impact on stormwater pollution problems. To understand stormwater pollution, one should note that anything that goes down the storm drain goes directly to streams, lakes and finally the sea. The two most significant pollutants are sediment and faecal coliform bacteria and with other household and industrial products/waste also finding its way into stormwater system, causing minor to major problems (Lowly, et al., 2010).

Sediment comes from erosion of land under development, soils exposed due to lack of vegetation, steep banks and channels damaged by excessive flow, due to urbanisation, and construction sites. Large scale faecal coliform pollution is usually the result of sanitary sewer overflows, or lack of sewer installation, where the bucket system is used (mainly in the informal settlements in developing countries like South Africa). Contamination can also occur from domestic and wild animal waste entering streams and lakes (Lowly, et al., 2010).

To reduce the impact of stormwater pollution, engineers can ensure that areas are re-vegetated after construction to avoid soil erosion. Vehicles should be well maintained, to reduce oil leaks and limit break emission. Difficult to control in developing countries. Reducing runoff can be done by installing rain barrels or redirecting roof trays away from driveways and sidewalks into grassy or vegetated areas, which will absorb some of the runoff. These simple measures can significantly reduce the amount of polluted stormwater that carries pollutants into storm drains and streams (Armitage, et al., 2013).

b) Source controls

Internationally source controls are effective in a variety of designs, such as green roofs, rainwater harvesting, soakaways or permeable pavements. Green roofs are vegetated roofs, which are easy to fit onto any roof, especially commercial buildings where it will be hard to fit other sustainable drainage systems (Armitage, et al., 2013). See Figure 2-3 for an illustration.

Figure 2- 2- 3: British Horse Society Green Roof (Wikipedia, n.d.)

A typical installation of a rainwater harvesting system can be seen in Figure 2-4, where rainwater is harvested off roof tops into storage tanks. The water is channelled to the storage tanks by using the gutters and pipes around the house and gravity (CTCN, n.d.). The storage tanks should be lower than the collection area. Otherwise unnecessary electricity could be used for pumps.

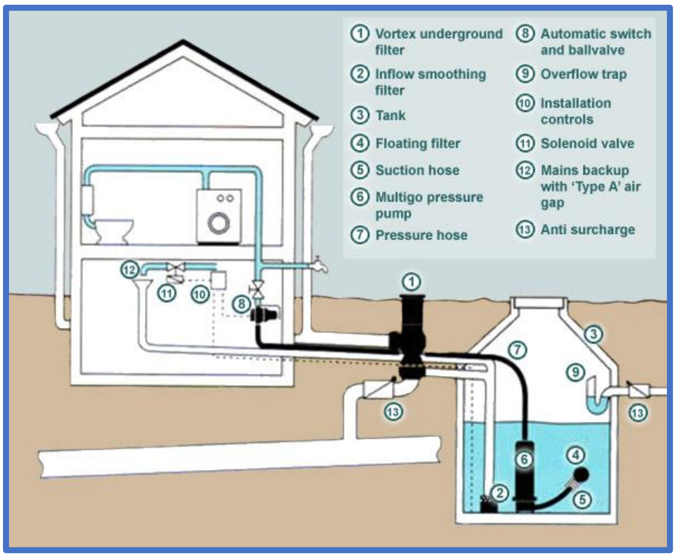


Figure 2- 4: Typical installation for rainwater harvesting at a house (SuDS Wales, 2018)

A permeable pavement design is illustrated in Figure 2-5. It is constructed of load bearing permeable concrete pavers laid on top of an open grade bedding course which helps with filtering of pollutants. The bottom layer, an open graded subbase, also has an underdrain pipe, which is used to transport water to temporary storage to be further used as a non-potable water source (Armitage, et al., 2013).

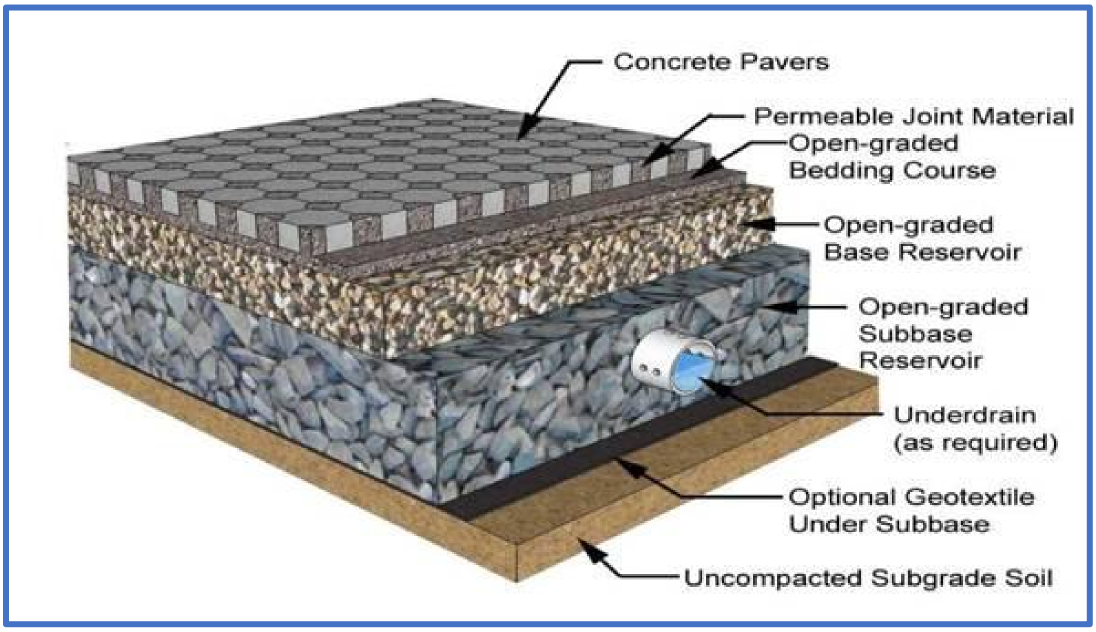


Figure 2- 5: Typical section of a permeable pavement (Smith, 2006)

c) Local controls

Localised controls include filter strips, swales, infiltration trenches, bio-retention areas and sand filters. These technologies are quite efficient, since they not only clean the water from surface pollutants, but also reduce flood peaks significantly. These control measures should be used instead of concrete canals that transfer water away from the roads as quickly as possible, causing large volumes of water to flow downstream and cause flooding and erosion on river banks in areas where drainage is not well maintained.

Figure 2-6 illustrates a basic filter strip, used next to roads and parking areas, where the runoff is directed out of the road, to be slowly filtrated. Filter strips are densely vegetated areas (primarily grass) and uniformly graded and are the first infiltration zone for treatment trains such as bio-retention gardens, infiltration trenches and swales (Melbourne Water Corporation, 1999, cited in (Armitage, et al., 2013)). Filter strips can therefore be used to reduce flood peaks by re-directing runoff and spreading it into sheet flow. There are two types of swale technologies available, dry or wet swales. Dry swales are used to filter all runoff volumes passing the system. Wet swales are vegetated trenches used to generate a marsh area such as in wetlands (Armitage, et al., 2013).

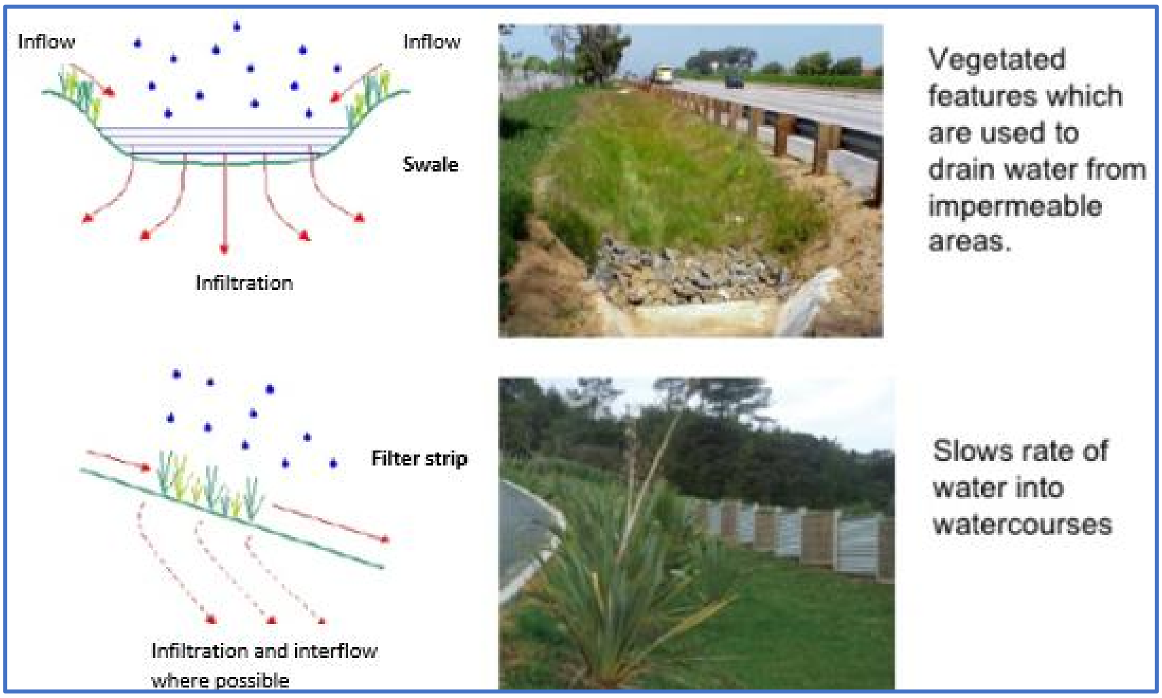


Figure 2- 6: Example of a Swale and Filter strip (CKMCforStudents, 2010)

Figure 2-7 illustrates a basic design of an infiltration trench. It is lined with a geotextile and filled with large course granular rock ((Hobart City Council, 2006) cited in (Armitage, et al., 2013)). As with filter strips, infiltration trenches reduce peak flow runoff from roads and parking areas. It is also used between residential units for sustainable drainage measures (Armitage, et al., 2013) Infiltration gardens can reduce up to 90% of heavy metals, coliform bacteria, organic matter and sediment from the runoff water ((Field & Sullivan, 2003), cited in (Armitage, et al., 2013)). Filter strips can be found along highways and main roads around South Africa.

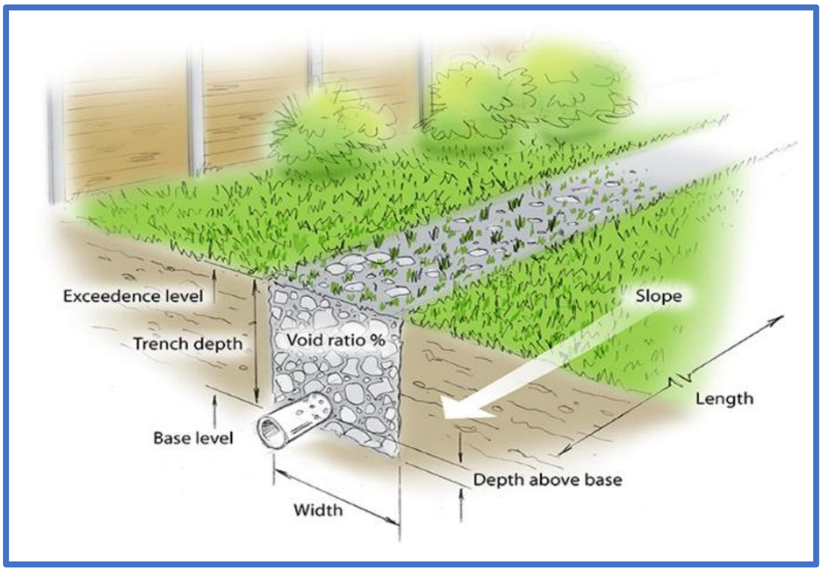


Figure 2- 7: Infiltration trench (XP Drainage, 2017)

A typical bio-retention garden design is illustrated in Figure 2-8. The garden is in a depression, where various processes are used. These may include absorption, filtration, biological uptake and sedimentation ((Debo & Reese, 2003) , cited in (Armitage, et al., 2013) pg. 31). Under the Design chapter a preliminary design for the engineering parking lot provides more information regarding bio-retention gardens.

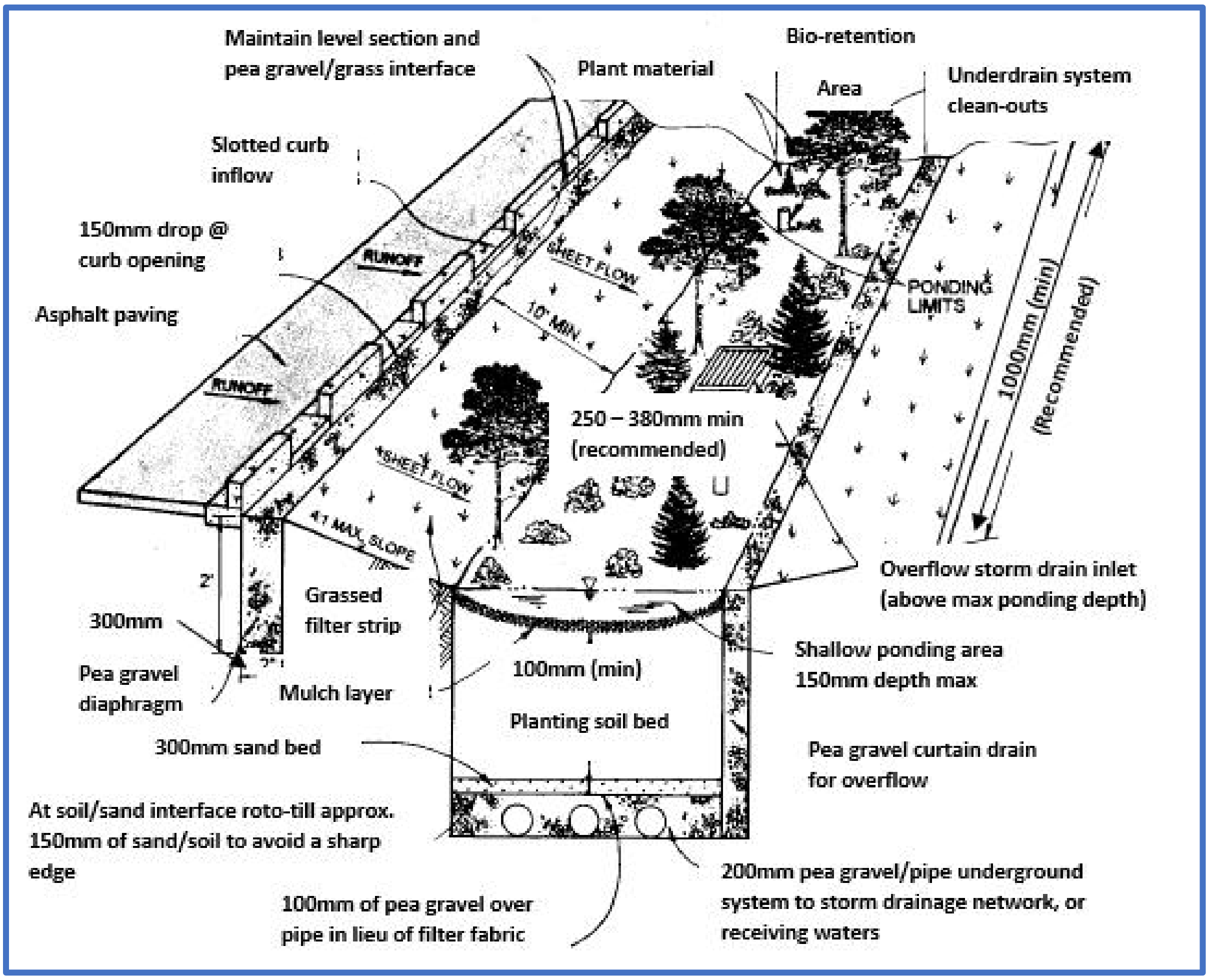


Figure 2- 8: Bio-retention garden design (Prince George's County, 1993)

Sand filters are used to capture and treat stormwater. The excavated basin is filled with sand and an underlying drainage system (Urbonas, n.d.). The runoff is collected in the basin and slowly infiltrates into the sand where it is transferred to the stormwater drainage system (Urbonas, n.d.). A typical sand filter can be seen in figure 2-9.

Figure 2- 9: Sand filter example (South East Metro stormwater authority, n.d.)

d) Regional controls

Detention ponds, retention ponds, constructed wetlands are often used as the final defence mechanism to mitigate the impacts of the quality and quantity of the runoff. Detention ponds are primarily used to reduce the peak flow of a storm event, where retention ponds provide a reduction in peak flow, as well as improving the quality of the water (Kruger, 2013) . See figure 2-10 for example of a detention and retention pond.

Figure 2- 10: Well-maintained detention (Stormwater Partners, n.d.) and retention pond (FloridaCleaning.com, n.d.)

Figure 2-11 illustrates a constructed wetland. A constructed wetland is designed to mimic a natural wetland and can significantly reduce particulates, heavy metals, and dissolved nutrients. The wetland is aesthetically pleasing and can form a habitat for bird, fish and other wildlife species. Slow flow through the wetland is ideal for the removal of pollutants. It should be noted that over time, a wetland can have sediment build-up and therefore lose its functionality (Armitage, et al., 2013).

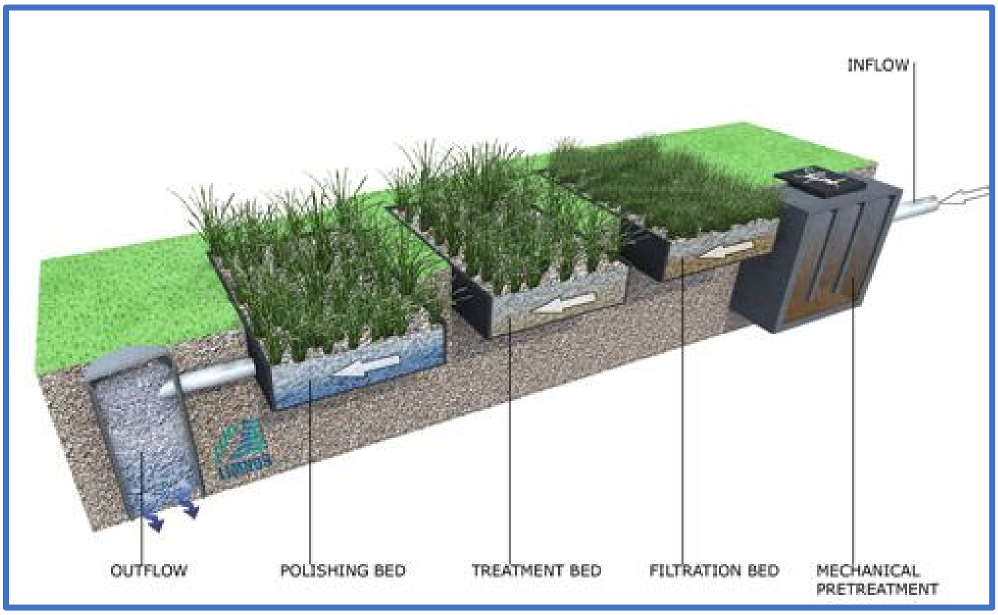


Figure 2- 11: Constructed wetland design (Browning, et al., 2013)

2.3 Different methods of sampling stormwater

There are three different methods to collect stormwater samples as reported by Washington Stormwater Department, these methods are: a) Catch basin sampling; b) Open ditch sampling, and c) Sheet flow sampling.

2.3.1 Catch basin sampling

The method that was used for sampling of stormwater in this study. A bottle was attached to a pole, with cable ties and lowered to the outlet pipe of the draining system. This method is discussed in more detail in Chapter 3: Methodology. For the catch basin sampling method was best fitted for the sampling of stormwater at the chosen site.

2.3.2 Ditch sampling

Firstly, check if the stormwater to be sampled only comes from the facility which is required to conduct the sampling, and not from any other facilities or streams. When finding the ditch, check the size of the ditch, if it is too small for the sample bottle, prepare the ditch by deepening the ditch (Stormater Sampling Techniques, 2015) . When the sample area is deep enough for the bottle, line the area with plastic. Before taking the sample, ensure that any settlement or debris has settled. Point the bottle upstream and fill the bottle to the desired level (Stormater Sampling Techniques, 2015).

Always use clean gloves, and do not touch the top of the bottle, for any cross contamination. Also, when sampling is completed, mark the bottle with the time and date, and place the sample in a cooler with ice. Finally, take the cooler to the nearest lab to be tested (Stormater Sampling Techniques, 2015).

2.3.3 Sheetflow sampling

For this sampling method various equipment for the process is needed:

1. 3 x 8 Litre Reseal able bags
2. 1 x 1 Litre resalable bag
3. A shovel handle or a similar device to create a dam
4. Scissors

The samples must be collected within the first 30minutes of the storm event (first flush phenomenon) (Minesota Pollution Control Agency, 2015).

Firstly, cut off the top and two side of one of the 8Litre bags, and unfold the bag. Fill the other two 8 litre bags about a quarter full of sand, squeeze all the air out of the bag and seal the bag shut (Minesota Pollution Control Agency, 2015). Also cut the top of the 1Litre bag, which will be used for sampling of the water temporary container (Minesota Pollution Control Agency, 2015).

After all the preparation is done, go outside and find a flat smooth area that can be represented as a sheetflow runoff (Minesota Pollution Control Agency, 2015). Lay the larger plastic sheet down on the ground in the direction of the stormwater flow. Place the two sandbags on the sampling surface so that it can create a funnelling effect, see Figure 5.1. (Minesota Pollution Control Agency, 2015). Place a shovel handle, or similar device, see Figure 5.1, under the plastic, which will help form a dam effect for collecting of the water (Minesota Pollution Control Agency, 2015).

Figure 2 - 12: Sheet flow sampling method 1 (Minesota Pollution Control Agency, 2015)

Take the 1Litre bag and place it over the shovel handle (or similar device), and place your fingers inside the bag to open the bags mouth, allow the water to flow inside the plastic bag (Minesota Pollution Control Agency, 2015). Lift the top of the bag to transfer the sample to the bottom of the bag, continue until you have enough stormwater in the bag (Minesota Pollution Control Agency, 2015). See Figure 2-13.

Figure 2-13: Sheetflow sampling method 2 (Minesota Pollution Control Agency, 2015)

When there is enough water in the sample bag, shake it well before pouring the sample into the sampling jar (Minesota Pollution Control Agency, 2015). When pouring the water into the bottle, do not place hands on or inside the bottle, possibility of contaminating the sample (Minesota Pollution Control Agency, 2015).

For organic material preservatives needs to be poured in the bottle, one should be careful about it can be very acidic (Minesota Pollution Control Agency, 2015). When finished with each sample, the time and date must be recorded on the bottle, also the time it took to take the sample. Pack the sample into the cooler, to be taken to the laboratory for testing (Minesota Pollution Control Agency, 2015).

2.4 International Stormwater Management Practices

2.4.1 Introduction to different stormwater management systems

In the past, the issue of stormwater pollution has been generally neglected internationally. However, over time onsite treatment became a consideration, which lead to actions being implemented to alleviate fresh water system pollution. Currently this includes common international solutions such as raingardens, bio-swales, wetlands etc. Urban areas are expanding due to increased urbanisation worldwide. This has a large impact on the urban natural water bodies that sustains aquatic ecosystems and human needs. Therefore, the need for stormwater management has become of great importance. Many countries have implemented sustainable drainage systems with great success.

Developed countries, like North America, Australia, New Zealand and Europe, have published and implemented manuals to manage stormwater for flooding, increase biodiversity, improving the microclimate and cleaning surface waters (Fletcher, et al., 2014) . These manuals provide an integrated approached on various sustainable methods to manage stormwater and minimise pollution. However, there is no general trend in specifications (not standardised). For example, one guideline would suggest different slopes in runoff canals. Therefore, design and implementation of structures for a specific purpose currently required more research.

A study conducted by Fletcher et al. (2014), has found that while different countries use the same type of technologies, they use different terminologies, which can be confusing (Fletcher, et al., 2014). Therefore, should a manual be prepared for developing countries (e.g. South Africa), special care needs to be taken to optimise the manual to allow everyone to understand and implement it with ease. This should consider that South Africa has vast biodiversity, and each development must be designed according to its own natural environment to optimise the drainage system.

Since the 1970's, management of stormwater has grown starting with Low Impact Design (LID) and Low Impact Urban Design and Development (LIUDD) where these measures were mainly used in North America and New Zealand (Fletcher, et al., 2014). The first approach (LID) was implemented in Vermont (USA) to make stormwater management more cost effective, by using the "design with nature" approach ((Barlow, et al., 1977) cited in (Fletcher, et al., 2014)). The aim of this method was to design system that works with the environment rather than against it (Fletcher, et al., 2014). LID was developed for small scale stormwater treatment systems, to treat the runoff before entering the source by using: swales, green roofs and bio-retention systems (Fletcher, et al., 2014).

A French manual was written in the 1980s, named Alternative techniques (ATs), or Compensatory Techniques (CTs) (Fletcher, et al., 2014). The purpose of the manual was to allow engineers to move away from the rapid disposal of water via stormwater drainage in their designs. With rapid urban growth in Paris during this time, concerns for the health and environment of the city needed to be considered, and the French moved to more natural approach with ATs. These systems were not only concentrated on pollution and drainage controls, but also on improving the standard of living for the city. These techniques were used to limit the investment cost, as well as using urban land more sustainably. The new requirements ensured that every new development would have sustainable stormwater management systems. These systems include detention, attenuation, infiltration, and source control retention systems. (Fletcher, et al., 2014)

In the early 1990's, Australia developed their own Stormwater Management tool, which was called Water Sensitive Urban Design (WSUD), with a more defined approach by having four (4) main objectives in the design of stormwater control systems. The first objective was to manage the water balance, including: damages due to flooding (including erosion), groundwater volume, and surface, stream and river flows. The second objective was to improve water quality, including sediment trapping, protecting natural vegetation in riparian zones, reducing the pollutants in surface and groundwater etc. The third objective was to ensure and encourage water conservation by reducing irrigation requirements, recycling waste water, harvesting rain water and reducing the need for potable water supply. The fourth and last objective was protecting and maintaining water recreational areas, as well as water environments. (Fletcher, et al., 2014)

Integrated Urban Water Management (IUWM), also used in Australia, is a much broader method for managing stormwater. The system considers the hydrological cycle of each catchment area to manage the stormwater specific to the site (Fletcher, et al., 2014). IUWM considers ecological, social, economic and environmental aspects of each development, for both the short-term and long-term. (Fletcher, et al., 2014).

Sustainable Urban Drainage Systems (SuDS) are broadly used and is a source of guidelines and technical control systems for stormwater in Europe, including Scotland, Wales, and England, who have made it part of their legislation to follow the principles set out by SuDS for any new development since 2003. England has included the SuDS manual in their Flood and Water Management Act in 2010 (Fletcher, et al., 2014).

Best Management Practices (BMPs) are used in North America and Canada; the main objective of BMP is ultimately to prevent and reduce pollution. BMP standards form part of the US Clean Water Act 2011, initially published in 1972. The BMP was already in use since 1949, but then only for managing agriculture water supply, whereas it recently became a more universal tool for information, data and guidance on pollution prevention of all surface water. In the past, BMP practices were focused on non-structural methods, such as maintenance, operation procedures, and training, but the updated BMPs include structural practices, such as infrastructure and engineering methods. The updated BMP practices are grouped into four different categories, 1. Detention devices; 2. Recharge devices; 3. Housekeeping practices; and 4. Others (Fletcher, et al., 2014).

In 2008 the US National Research Council of the National Academies of Engineering and Science, found that the BMP was too vague, and concluded that a new system needs to be developed and implemented. Stormwater Control Measures (SCM) were subsequently developed and provides much improved detail on which structural and non-structural systems are required. By developing the SCM, the US is not abandoning BMP, but improving on it (Fletcher, et al., 2014).

Green Infrastructure (GI) is another method of managing stormwater, where GI goes beyond just stormwater management. It was first introduced by landscape architects and ecologists through introducing green spaces in urban environments (Fletcher, et al., 2014). Using more GI can move the world forward in managing stormwater and distribution of stormwater through source control and treatment, for cleaner water.

In conclusion there are many technologies and management systems around the world, but these are currently mostly found in developed countries.

2.4.2 International case studies

SuDS case studies in the Netherlands shows that there is an overall increase in cost for the implementation of the systems, where the systems implemented are to a much larger scale than what is found in America. In the Netherlands cost is not what the public is concerned about but being more environmentally conscious about their surroundings and thinking of the long-term benefits. Australia is in the forefront for sustainable cities and campuses, after the millennial drought and intense flooding they started looking at stormwater as a resource.

These case studies show that community approval and involvement is of utmost importance. Awareness first must be taught by working with the environment and not against it. These types of principles are easier to teach in developed countries like Nederland. Developing countries like South Africa struggle with change, and much work still needs to be done with environmental awareness in cleaning waters.

2.4.2.1 The Netherlands

Europe uses SuDS for urban areas such as parks and residential areas. The various case studies show that most of the areas are close loop systems which are easier to control. Much attention is given to preventing water from outside entering the site / area to be able to recycle most of the water. Little attention is given to groundwater, although one of the case studies uses a retention pond of 40 metres deep. The Netherlands have some problems with their groundwater, as infiltration is easy. (Birch, et al., 2008)

Currently it is expensive to implement SuDS systems in the Netherlands, but if more SuDS systems are implemented it would be more cost effective. The increase in knowledge and professional confidence in new technologies will influence management practices, contractor trust, legislation, public participation and interest. (Birch, et al., 2008)

The case studies concluded that as stormwater systems are not invisible it should be aesthetically pleasing, and public participation is of utmost importance from the start of the design process. For new developments stormwater design should be implemented in the early stages of the design phase and include all aspects of flood and pollution control, aesthetics and social inclusion. (Birch, et al., 2008)

Two of the case studies concluded that it is not easy to design with only a landscape architect in the team. They therefore included civil and environmental engineers, hydrologists, biologists, chemists, social scientists, school and pre-school teachers, artists, entrepreneurs, contractors, architects, and residents from all ages. (Birch, et al., 2008)

It should be noted that SuDS are not providing one solution to a problem, but that it is a series of various technology solutions to be customised to different needs of an area, therefore it is a flexible method of management. One development implemented various aspects by addressing traffic, the needs for better recreational facilities, involved the community, and aesthetic upgrading (Birch, et al., 2008) . This case study summarised the following questions to answer when conducting the baseline assessment to decide on the systems to be implemented in the area:

1. How is the topography?
2. What are the soil conditions?
3. Groundwater levels in the winter and summer?
4. What are the contamination levels; visibly and measured?
5. What is the history of the site?
6. What is the local awareness level?
7. What is the level of commitment from all the various stakeholders?

(Birch, et al., 2008)

The studies generally concluded that, when designs should not be too complex, otherwise it gives more room for failure, and all designs should be site specific. Design should be done with a holistic approach (applying as many integrated aspects as possible), and round table discussions should be conducted with important stakeholders. Management practices should be implemented as soon as possible. Ongoing maintenance should form part of discussions, as is demonstrated in a case where it was found that the wadis installed clogged due to the oak leaves, another site there was destruction of grass pavers, and the filtration boxes malfunctioned, and permeable pavements got clogged. (Birch, et al., 2008)

2.4.2.2 Australia

1. Christie Walk, Adelaide, South Australia

Christie Walk is a community of 27 homes with half an acre of gardens, developed in 1998 and completed in December of 2006. The community is named after Scott Christie, an environmental activist. The development is used as a prototype for cities in Australia to be used at a larger scale, incorporating sustainable development ideas and implementing a community feeling. (Urban Ecology Australia Inc., 2013)

For water saving purposes, they installed low flow shower heads, flow restrictors, low water usage plants, communal laundry facilities, and subsurface irrigation systems. Stormwater is used for flushing toilets and irrigating the landscapes and rooftop gardens. The development lead to an overall reduction in wastewater and contamination loads leaving the site. (Mitchell, 2006)

Figure 2- 14: Photo of one of the rooftop pools at Christie Walk (Urban Ecology Australia Inc., 2013)

2. New Haven Village, Adelaide, South Australia

New Haven Village is a medium density residential development completed in the late 1990's. Compared with other similar sized developments, they have found a 30% reduction in water usage and almost total elimination of waste water discharge, including stormwater. There is an onsite wastewater treatment facility, and a grinder pump sewer system (Mitchell, 2006).

The first 50m^3 of rainwater is harvested from every rain event, with overflow water diverted to a sports field acting as a retention pond. Recycled wastewater is used for flushing toilets and irrigation. There have been problems over the years with the reuse of the wastewater, such as odour and colour, but most of the occupants of the development have reported little to no concerns (Binnie & Kimber, 2008).

3. Homebush Bay, Sydney, New South Wales

Homebush Bay was previously used as landfill, navy deployment yard and slaughterhouses (Lloyd, 2000) . The area was transformed into an innovative water treatment facility for the 2000 Olympic Games. The facility included treating stormwater and wastewater, reducing the use of potable water, and protecting the surrounding fauna and flora in the area.

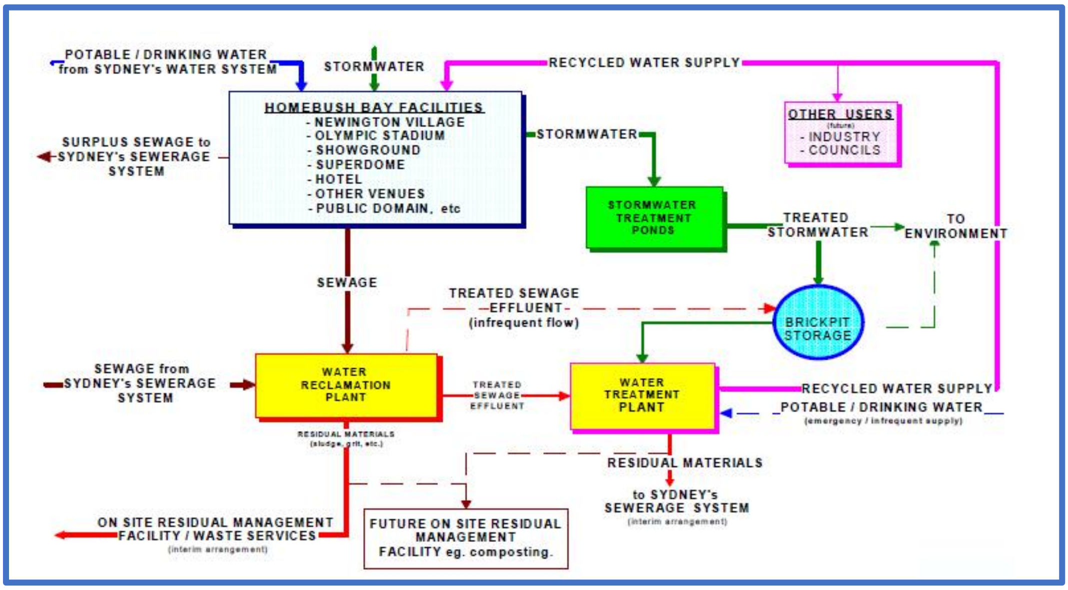


Figure 2- 15: Flow diagram of Homebush Bay management scheme (Lloyd, 2000)

Figure 2-15 above shows the flow diagram of how Homebush Bay is managed. The stormwater runoff runs into the system, treatment starting with the water firstly going through a gross pollutant trap, and then through swales and/or wetlands. The reclamation plant is where the balance of the stormwater, as well as sewage is transported where the water is stored in a brick pit storage facility. The water is then used for irrigation, toilets and firefighting. The potable water use has been reduced by 50% annually, due to recycling of water and water saving devices. The quality of the water complies with Australian quality of water standards. (Lloyd, 2000)

4. Figtree Place

Figtree Place is a housing development with 27 units that was designed with stormwater harvesting systems, such as underground rainwater tanks and an aquifer. The overall reduction in potable water usage is approximately 60% and increase in development cost is only 0.5%. The quality of the water complies with the Australian drinking water standards. (Lloyd, 2000)

Figure 2- 16: Schematic layout of Figtree Place

Figtree was fitted with a detention basin, as can be seen in Figure 2-16 above, which is used to temporarily store and treat the runoff. There are five rainwater storage tanks that collects the runoff from roofs. The harvested stormwater is used for toilets, irrigation, washing buses, and hot water for the houses (ensuring that any pollutants are killed before use). (Lloyd, 2000)

5. Mawson Lakes, Adelaine

Mawson Lakes is self-sustaining city, with approximately 10,000 inhabitants. The city was designed for sustaining the natural water supply and ecosystem. Wastewater is recycled and treated in the sewage treatment plant. The treated water is chlorinated and treated with dissolved air flotation and a filtration plant. Stormwater from the Parafield Airport is diverted to the constructed wetlands where it is biologically treated. All the water is diverted to a large tank, which pumps water to a separate reticulation system, which is used for recreational facilities, and irrigation purposes. The overall potable water use has been reduced by 50%. (Cullen, n.d.)

2.5 Stormwater harvesting

2.5.1 Introduction

Urban development has a significant effect on the natural environment, especially the aquatic life in streams flowing through developments (Mitchell, et al., 2007) . Stormwater management throughout the world has developed and grown significantly over the past few decades, but South

Africa still has a long way to go in this regard. Whereas stormwater management systems all over the world were previously purely designed for flood control and protection, in recent years, management of stormwater has grown to include pollution control, ecological regeneration, and enhancing the value of stormwater as a resource (Mitchell, et al., 2007).

Stormwater harvesting around the world for potable water supply is not a recent topic of discussion and has become popular among countries such as Australia, Germany, and America (Kazemi & Hill, 2015). New South Wales in Australia has successfully implemented stormwater harvesting systems, where up to 40% of the potable water supply is gathered through stormwater harvesting (McArdle, et al., 2010).

An important goal for stormwater services is the preservation of water quality in the streams, rivers and lakes. Streams provide habitat for wildlife, corridors for recreation, and buffers to soften our natural environment. They are significant assets to our quality of life. Water is the life source of these corridors, and maintaining its quality is imperative into protecting them.

Stormwater management in developed countries provide a service of continuous monitoring of the quality of water throughout the watershed of the cities. Various areas have real time monitoring stations to provide an accurate measure and good overall picture of water quality, where targeted polluted areas can be quickly identified, and appropriate action taken.

2.5.2 Benefits

The main objective of stormwater harvesting is to provide a valuable source of water supply (Mitchell, et al., 2007) . Stormwater treatment for harvesting also enhances the health of the downstream aquatic ecosystems and riparian zones (Mitchell, et al., 2007) . South Africa is a dry country, where the water uses in cities, especially Cape Town, is exceeding its sustainable limits. Therefore, stormwater harvesting used as an alternative water supply can be highly beneficial to drought-stricken areas (Fletcher, et al., 2007). According to a study conducted by Monash University, Australia, the harvesting of urban stormwater has the potential to conserve water resources and natural environmental flows (Fletcher, et al., 2007).

2.5.3 Challenges

Finding a site with low pollution control measures necessary for harvesting has many challenges, including:

- Stormwater harvesting systems is not “one-size-fits-all” technology, each area has its own pollution and flood control measures needed.

- Attention to downstream impacts, due to the reduction in flow should be calculated.

(Fletcher, et al., 2007)

2.5.4 Designing harvesting systems

Studies conducted by Monash University, Australia, suggest that there are five core functions that should be part of the integration of stormwater harvesting: (1) collection, (2) treatment, (3) storage, (4) flood and environmental protection and (5) distribution to end users (Mitchell, et al., 2007).

a) Collection

Stormwater collection methods can be SuDS systems already in place, such as bio-retention gardens, swales, or infiltration trenches. There may be losses due to infiltration into surrounding soil or evapotranspiration (ET). ET and infiltration are dependent on the size of the surface area, climate, and type of soil. Stormwater should be harvested during small to medium rainfall events: high precipitation tends to have more constituents. Impervious areas decrease the amount of water that can be harvested, due to increase flood peaks where the flood volumes pass the catchment area before being able to drain into the harvesting technology (Mitchell, et al., 2007).

b) Treatment

Stormwater is mainly harvested for non-potable uses such as: toilet flushing, firefighting, irrigation, industrial uses, groundwater recharge and car washing. Therefore, the stormwater will have to be treated to the extent where it is safe for non-potable uses. If needed for potable uses, further treatment precautions, and extra testing will have to be incorporated into the treatment train (Numen, 2013).

Additionally, hydraulic loading needs to be considered, for if the reservoir used for the harvesting is full, there should be a bypass, to "minimise re-suspension of fine sediment, and attached pollutants" (Numen, 2013).

c) Storage

The storage capacity is dependent on the magnitude of temporal pattern, water demand, and catchment characteristics. Storage is dependent on maximising volumetric reliability (Rainfall) and minimising storage size and cost. (Mitchell, et al., 2007)

d) Flood protection

Designing stormwater harvesting systems it is needed to ensure a slow release of water before a storm event. This will also protect the environment, due to water being cleaned with biofilters before it is released in the environment. The harvesting system design ensures conservation of water, providing a constant water supply. (Mitchell, et al., 2007)

e) Distribution

Depending on the spatial scale, density, and inclusion/exclusion of firefighting requirements; the water can be used for open space irrigation system, or non-potable uses such as toilet flushing.

2.6 Bio-retention systems

A bio-retention system is used to collect stormwater in a depression in soil, and treat the water using a specific filtration system and plant species. The filtration system is designed specifically for the end use of the stormwater, and the type of pollution that would be treated. The plant species is chosen specifically for the type of pollution that would be treated and should be indigenous plant species that would thrive in the environmental conditions. As the water moves through the filter media the pollutants are captured by the fine materials. The water that is treated is transported from perforated drainage pipes that is placed under the filter media to downstream drainage systems, waterways or captured for harvesting. (Wettenhall, et al., 2014)

Various studies have been conducted on the efficiency of bio-retention systems. It was found that these systems remove between 70 to 85 % of phosphorus in the water, but have poor removal of nitrates in the water, where in some cases there was an increase (Davis, et al., 2006) . The bio-retention removes between 96 to 99% of oil and grease, up to 90% reduction of polycyclic aromatic hydrocarbons (PAHs) (DiBlasi, et al., 2009). Another study indicated that areas receiving acid rain (pH between 5 and 6) at the inflow provided an outflow to near perfect pH levels between 6 and 8 (Davis, 2007) . The Biochemical Oxygen Demand (BOD) can be reduced on average by 63%, with faecal coliform reduction of around 90% (Hunt, et al., 2008). A two-year study in North Carolina on a bio-retention cell indicated a reduction of 69% faecal coliforms and 71% reduction in E. coli counts (Hunt, et al., 2008). (Roy-Poirier, et al., 2010)

A study conducted by the Water Environmental Research (WER) of Australia showed the effectiveness of metal removal of bioretention facilities. The study showed that up to 100% of the metals were removed, with final Cu and Pb levels being less than 5 µg/L and Zn being less than 25 µg/L. (Davis, et al., 2003)

The bio-retention system can also manage the natural hydrological cycle. With an increase in urbanisation, impermeable surfaces, causing major flooding and reduction in groundwater recharge, bio-retention systems can be implemented to reduce the risks. The systems can reduce flood peak, recharge groundwater, provide cleaner surface waters and reduce pressure on urban streams (Wettenhall, et al., 2014).

There are 11 key components in designing a bio-retention system, these are:

1. **Filter media** – typically 0.5 – 1metre deep, with a mix of sand and loam
2. **Transition layer** – a coarse sand layer, known as the bridging layer, that prevents the filter media to move into the underdrainage
3. **Underdrainage** – typically perforated drainage pipes and fine aggregate
4. **Liner** – the liner depends on the type of bio-retention system being designed for, for it can be permeable or not, and it can underline the base of the system or the sides as well
5. **Hydraulic structures** – the hydraulic structures help that the system does not clog or overflow into areas that stormwater should be kept to a minimum, these structures can include: inflow, overflow, and outflow pipes.
6. **Bunds and embankments** – are used as a barrier for the temporary storage of the stormwater before being treated
7. **Extended detention** – a layer above the system where water can dam before filtrating into the system
8. **Vegetation** – as stated above should be specific to the type of pollution to be treated and be indigenous to the environment
9. **Course sediment removal** – a specific area where sediment from the runoff can be stored during the storm, and can be easily removed after a rainfall event
10. **Maintenance Access** – access should be provided for easy and effective maintenance
11. **Cleanout riser pipe** – a pipe that is not perforated that rises above the ground for easy inspection or cleaning of the drainage underground.

(Wettenhall, et al., 2014)

These guidelines were used as a basis for the preliminary design in Chapter 5.

Biofiltration systems is the use of different vegetation to remove pollutants from stormwater (Read, et al., 2008) . Currently, much research is still needed regarding biofiltration systems, knowing the best vegetation that removes pollutants effectively (Read, et al., 2008).

Phytoextration is the removal of contaminants out of soil, and Rhizofiltration is the removal of contaminants out of water (Filippis, 2015) . Research shows that the Brassica Juncea plant species can be used cleaning toxic metals in contaminated soil (Kumar, et al., 1995) . Another study showed that using water lettuce (Figure 2-15) can significantly reduce Cd and Pb in water, although the water lettuce lives in water, and needs to be constantly submerged in water to stay alive (Vesely, et al., 2011).

Figure 2- 17: Water Lettuce (Natures Beauty Creations, 2015)

2.8 Summary

Stormwater management for urban areas in South Africa channels water as fast as possible to the nearest watercourse, before any treatment or better use of the water. The quality of stormwater is important for the development of new projects and reduction of pollutants in streams and rivers.

Sustainable measures for managing stormwater internationally has been growing since the 1970's, where it is found that different countries use the same technologies but different terminologies. This can cause confusion for moving forward in the field.

The various stormwater control systems can be divided into four different categories: Good housekeeping; Source control; Local Control; and Regional Control. These categories can be sub-divided into different drainage systems, which reduce runoff, improve the quality of the water, and implement more green spaces. Green spaces include save water environments, creating awareness, reducing flood impacts, such as erosion, siltation and pollution.

The stormwater harvesting summarised under section 2.6, is provided as the basis for the preliminary design in Chapter 5. Note that the various control measures elaborated in section 2.4 does not cover stormwater harvesting as a local control measure. This indicates that stormwater harvesting is a technology that is not widely used in the management of stormwater, but dry areas like the Western Cape in South Africa can find it very beneficial for possible solutions for future droughts.

The final section under the literature review is a brief introduction on bio-retention systems, the benefits it has in reducing various pollutants in stormwater, and how it can help recover the natural hydrological cycle. The section also provides the general guidelines on how to design a bio-retention system, which was used in Chapter 5 for the preliminary design.

In conclusion, the climate is changing, wet areas are becoming wetter and dry areas are becoming dryer. Cape Town is falling within the dryer spectrum, and due to this new and efficient ways needs to be developed for sourcing water.

Chapter 3 Methodology

3.1 Introduction

This chapter details the onsite sampling method as well as the laboratory methods used to quantify pollutants in stormwater runoff from the study site. Total Particulate Solids (TSS), Inorganic Particulate Solids (ISS), and Volatile Particulate Solids (VSS) were tested in the University of Stellenbosch Water Quality laboratory. Metals (As, Cd, Cu, Pb and Zn) were tested at the University of Stellenbosch Central Analytical Facility (CAF). Samples were collected during rainfall events described below.

Various sampling areas within the town of Stellenbosch were considered for the study, and many sites had high potential for good data collection. The Stellenbosch University Engineering parking lot was ultimately chosen. Logistics considerations largely influenced this choice, and this included ease of access to the laboratory during night time collections, student safety, sample care considerations (minimisation of time lapse before refrigeration etc.) and timeous on-site support from University staff.

Due to the occurrence of a drought during the research period, the number of dry days exceeded those of previous years. Normally, during the rainy season in the Stellenbosch area it often rains at least a week at a time, but during the winter months of 2017 the rainfall decreased to one rainfall day approximately every two weeks. A general observation from the surrounding communities of Stellenbosch.

3.2 Study site

Figure 3-1 shows an image of the parking lot used as the study site, located at the Faculty of Engineering, University of Stellenbosch, Stellenbosch, South Africa. The roof runoff from the Engineering building also contributed to the stormwater at the sampling point as did all the water from the water laboratory roof. The parking lot has a very flat slope towards the South-Western side of the parking lot, where the sampling point can be seen illustrated in Figure 3-2.

Figure 3- 3- 1: Parking lot study site (Google Earth,2017)

Figure 3-2 illustrates the parking lot drainage layout. The thick blue lines indicate the storm drainage pipes, whilst the red circle in the left bottom corner indicates where the samples were taken.

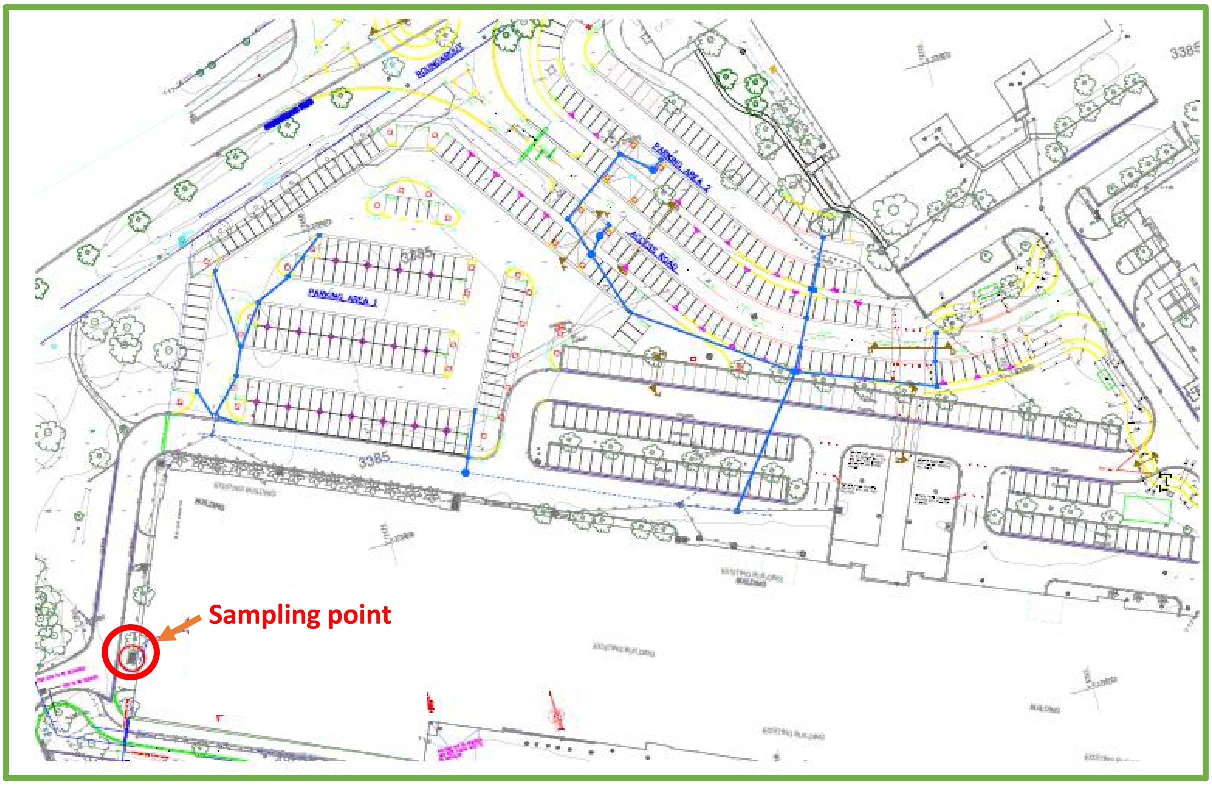


Figure 3-2 Stellenbosch University Engineering Faculty Parking Lot (DCD GROUP Ltd., 2013)

Figure 3-3 indicates the different catchment areas mentioned in Table 3-1: The yellow area indicates the parking lot, the red area the water laboratory (very steep roofs, up to 45°), and the blue area the structures concrete laboratory as well as a few offices, all of which have flat roofs.

Figure 3-3: Different catchment areas

The catchment areas were determined using AutoCad (AutoCad, 2017), and the three different area sizes are shown and summarised in Table 3-1 below.

Table 3- 1: Study site catchment areas (Figure 3-3)

Catchment description	Total area Estimated
Red: water lab roof	4 023m^2
Yellow: Parking Lot	12 008 m^2
Blue: Concrete lab roof	2 568 m^2
Total	18 600m^2

3.3 Sampling procedure

There are three different methods to collect stormwater samples as reported by Washington Stormwater Department, these methods are: a) Catch basin sampling; b) Open ditch sampling, and c) Sheet flow sampling.

The sampling procedure used for this study can be termed as "catch basin sampling" as described below. Table 3-2 provides a list of all the equipment used during the sampling process.

Table 3- 2: Sampling equipment list

Num.	Equipment	Preparation
1.	750ml bottles	Marked during sampling, due to precipitation times being unpredictable
2.	100ml bottles	Used to take filtered and unfiltered samples to the Central Analytical Facility (CAF)
3.	Nitric Acid	Sample stabilisation, minimum of 24hours after samples were taken.
4.	Gloves	Extras for possible contamination or breakage
5.	Extension pole	750ml bottles were attached for each sample with cable ties
6.	Rain gauge	Placed on the study site parking lot with minimum obstacles which may prevent rain from being caught
7.	Cooler box	Storage of samples during transport to remain cool
8.	Timer	Recording of time between sampling

A rain gauge was installed at the back of the engineering faculty, ± 300 metres away from the sample point, away from obstructions and provided accurate readings when compared with local meteorology sites (La Colline, Stellenbosch Weather Station). The rain gauge was installed within the parking lot, as can be seen in Figure 3-4.

Figure 3-4: rain gauge in the parking lot

Figure 3-5: Sampling point

Samples were taken by attaching a container to a two-metre extension pole, the container was then lowered down into the manhole and held by the drainage pipe to be filled with stormwater from the sampling position, as shown in Figure 3-6 above. The full bottle attached to the pole was then brought to the surface and decanted into a different sample bottle. Each bottle was marked with a number, the time and date it was taken, the depth of flow out of the pipe, and finally the rain gauge readings at that time. The depth of flow was not easy to obtain, due the pipe being 2metres from the surface – the depth of flow was therefore estimated, based on the visual height of the flow from the top of the sampling hole, and knowledge of diameter of pipe.

After all the samples taken for the storm event, it was taken to laboratory after the storm event to be stabilised with Nitric Acid, and preserved in a fridge at 4°C. The samples were kept in the fridge until further analysis could take place.

3.4 Metals testing

The samples were preserved immediately after sampling by acidification with a concentration of nitric acid to pH<2. The amount of Nitric Acid needed was 1.5ml HNO_3/L, therefore, approximately 5 drops of Nitric Acid were added per sample. This preserved the metals in the stormwater to prevent them from binding to the container walls. Nitric acid has the capacity to preserve samples for up to 6months in general and 5 weeks for Mercury. After the nitric acid was mixed well with the sample, the containers were placed in a refrigerator at 4ºC. (Rice, et al., 2012)

After the samples were prepped with Nitric Acid and refrigerated, the samples were filtered before being transported to the CAF (Central Analytical Facility) laboratory. The smaller 100ml bottles were marked in accordance with the sample number on the 750ml bottles, with a filtered and unfiltered bottle for each sample taken. The filtered samples was filtered through a 45µm filter.

The samples were tested by inductively coupled plasma mass spectrometry (ICP-MS), which is a type of mass spectrometry metre that can detect metals and several non-metals at concentrations as small as 10^{-15} µg/L.

3.5 Solids (TSS, VSS, ISS) testing

Additionally, the samples were tested for Total Particulate Solids (TSS), Volatile Particulate Solids (VSS), and Inorganic Particulate Solids (ISS) concentrations in the Water Quality Laboratory as discussed below.

3.5.1 Introduction

The equipment used for solids testing were as follows:

- 0.45 µm Filter paper (90mm diameter)
- Drying oven, 103 -105°C
- Desiccator
- Analytical balance (electric scale), capable of weighing to 0.001mg
- Furnace, 550°C

The equipment is shown in Figure 3-6 below.

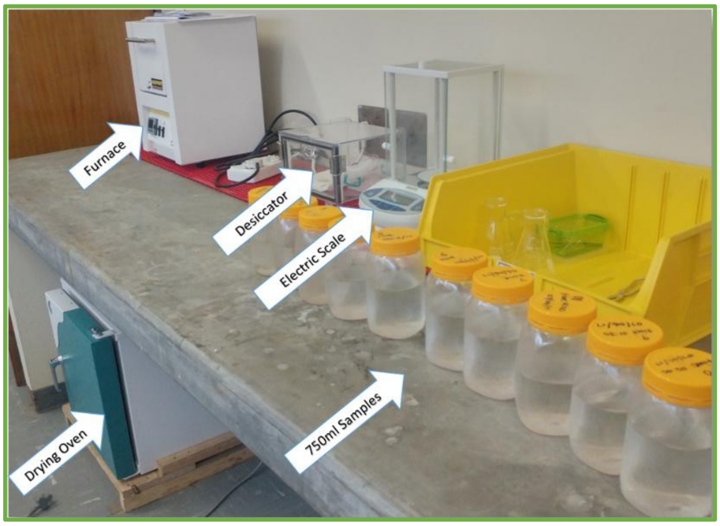
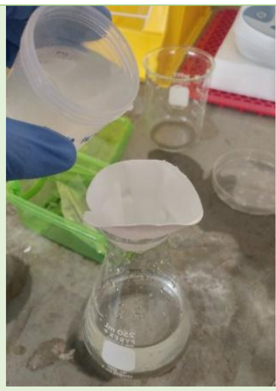


Figure 3- 6: Laboratory equipment used

3.5.2 TSS (Total Particulate Solids)

The best practice method of testing for TSS, is through gravimetric methods as shown and described in Table 3-3 below. (Fundamentals of environmental measurements, 2016)

Table 3- 3: Testing procedure for TSS

Num.	Procedure	Photos
Step 1	Weigh the dried filter paper on an electronic scale.	
Step 2	Weigh the dried crucible (placed in a drying oven for an hour before weighing)	
Step 3	Filter 100ml of sample through the filter paper.	
Step 4	Place the crucible with the filtered sample in a drying oven for an hour at 105°C (NPDES, 1971).	

Step 6	After 1 hour place the crucible with contents in the desiccator to cool to room temperature.	
Step 7	Weigh porcelain with contents as well as filter paper only with contents on an electronic scale and record the data.	
Step 8	Calculate the TSS, using the following equation: $\frac{mgTSS}{L} = \frac{(A-B)x1000}{sample\ volume, L}$ 3-1 A = weight of residue + weight of filter after drying ignition (mg) B = weight of filter before drying(mg)	
Photos: taken in the wastewater lab during testing procedure (Rauch,2017)		

(Zhang, et al., 2013)

3.5.3 ISS (Inorganic Particulate Solids)

The process of testing for ISS is described in table 3.4 below.

Table 3- 4: Testing procedure for ISS

Number	Procedure	Photos
Continue after the TSS procedure as follows		
Step 1	Place the crucible with TSS contents in a muffle furnace for an hour at 550°C	
Step 2	Place the crucible in the desiccator to cool to room temperature.	
Step 3	When at room temperature, weigh crucible and with filter individually on electronic scale and record data.	
Step 4	Calculate the ISS, using the following equation: $\frac{mgISS}{L} = \frac{(C-B)x1000}{sample\ volume, L}$ 3-2 B = weight of residue + weight of filter after ignition (mg) C = weight of residue + weight of filter before ignition (mg)	
Photos: taken in the wastewater lab during testing procedure (Rauch,2017)		

(Zhang, et al., 2013)

3.5.4 VSS (Volatile Suspended Solids)

Volatile Solids (VS) are determined by the solids that are lost when a sample is ignited in a furnace at 550°C (CorrosionPedia, 2017) . VSS is any carbon containing material, "excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates and ammonium carbonate" (EPA, 2017). It was calculated as follows:

$$VSS = TSS - ISS$$

3.6 BMP Data Selection

The study site data was compared to international data from the International Stormwater BMP Database (International Stormwater BMP Database, 2016) . The data was selected by first filtering out parameters that were not useful for comparing the type of parameter data obtained on-site with the BMP-Database. The BMP database measures the concentration for its various land uses with the use of Event Mean Concentration (EMC) (As described under the following section 3.8 – Due diligence):

1. Only Flow Weighted Composite EMCs were included for consistency. Grab samples were unrepresentative of the storm average concentrations and were excluded.
2. Only Surface Runoff/Flow data was included for comparativeness. Other sources such as groundwater were incomparable and were excluded.
3. Only concentration data was included. Units were typically reported in µg/L.
4. Some data inputs were -99999 values, which indicated data errors. These were removed from the dataset.
5. BMP Inflow data was identified and compiled. This data was typically runoff data from the case study catchments.

The following method was repeated for each element as well as for Total and Dissolved concentrations. The method is explained my means of using Arsenic (As) as an example below:

1. Case studies that were comparable to the research study site were identified. This is discussed in greater detail below.
2. The data was separated into Total and Dissolved data.
3. Any sample data that provided less than 10 sample concentrations was also filtered out. This was chosen due 10 storm events, which was compared with the BMP database.

Figure 3-7 below shows an extract of the BMP database.

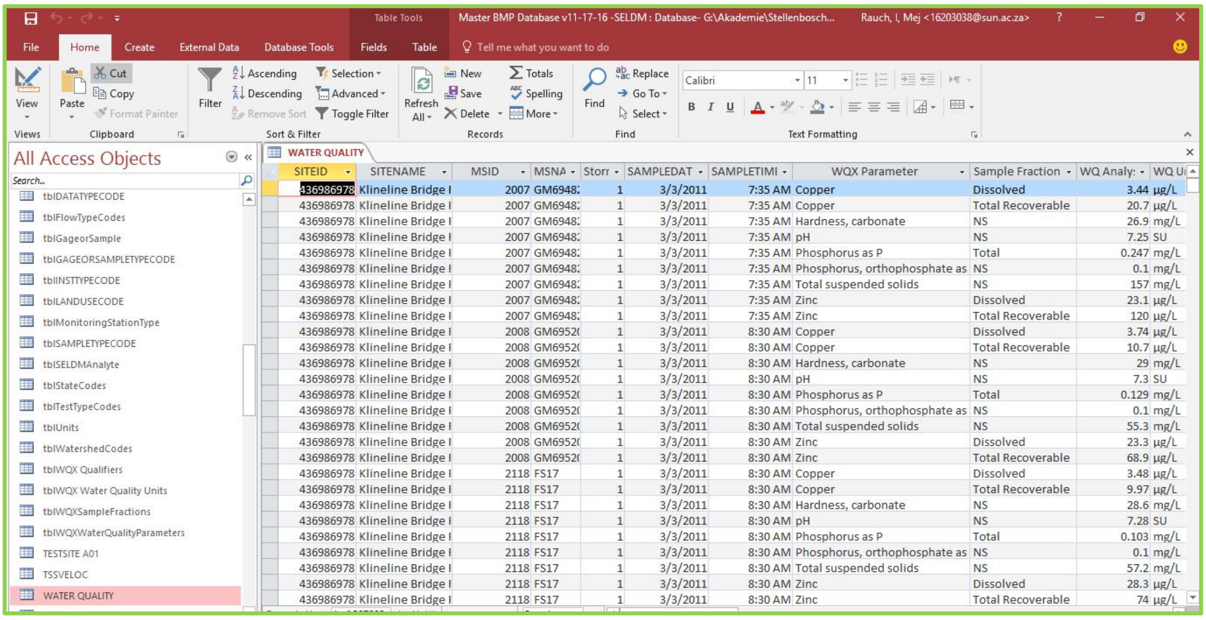


Figure 3-7: BMP database extract

Site selection

The included case studies were identified through first identifying the areas that will most likely provide comparable data to the study site. The land uses were found on a different Land Use spreadsheet in the BMP database. Parking lots were identified such as Park and Rides (P&R), where citizens will stop in the morning and take public transport to their jobs. The different site names can be found in Table 3-5, which provides a list of all the possible site names. Site information was inspected to ensure the site was in fact a parking lot. For Example, as can be seen below the Mitchell Community College is identified as a P&R in the database, which is believed to be a mistake, or there is a P&R elsewhere on the campus.

It was decided that “Office Commercial” land use type runoff can also be used, due to the parking area being in use during the same operating hours as an office building, 08:00 – 17:00. As can be seen in Table 3-5 many of the “Office Commercial” test sites are schools, universities and parking lots. “College Campuses” were also identified, but there was only one campus on the list.

The sites were further filtered by checking if there is any data for the constituents being studied, therefore, under “Sample Fraction”, the “Dissolved” and “Total” were selected, and under the “WQX Parameter”: As, Cd, Cu, Pb, Zn, and TSS were selected. The data in Table 3-5 below provides information available after filtering out the different land uses and cases as described above. Table 3-5 shows that from the chosen datasets five did not have any data, only one has values for TSS, and most of the datasets only had data for Cu and Zn.

Table 3- 5: BMP site names and Descriptions

Num.	Description	Test Site Name	Data
1.	Park & Ride	I-5/SR-78 P&R	Data for all the metals, Total and Dissolved, non for TSS
2.	Park & Ride	Termination P&R	Data for all the metals, Total and Dissolved, nothing for TSS
3.	Park & Ride	Albany Park and Ride NZ	Only data for Cu and Zn and only for Dissolved concentrations
4	Park & Ride	La Costa P&R	Data for all the metals, Total and Dissolved, non for TSS
5.	Park & Ride	Fayetteville Filterra	Only data for Cu and Zn, for Dissolved and Total concentrations
6.	Park & Ride	Mitchell Community College	No Data
7.	Park & Ride	Via Verde P&R	Data for all the metals, Total and Dissolved, nothing for TSS
8.	Park & Ride	I-95 Plaza Bioretention Cell	Data available for all metals except As, and both for Total and Dissolved, there were no data for TSS
9.	Park & Ride	Lakewood P&R	Data for all the metals, Total and Dissolved, non for TSS
10.	Office Commercial	UDFCD Modular Porous Pavement	Provides only values for Cu, Pb, and Zn, with Total and Dissolved concentrations
11.	Office Commercial	J Lot	No Data
12.	Office Commercial	KingstonPublicServicePavements	No Data
13.	Office Commercial	Ping-Lin Parking Lot	Only data for Cu and Zn and only for Total concentrations
14.	Office Commercial	Lakewood Shops	Provides only data for outflow
15.	Office Commercial	VU Porous Asphalt/pervious concrete comparison site	No Data
16.	Office Commercial	University of Toledo – Law	Very little data, only for Total

		School Parking Lot	concentration, and nothing for As or TSS
17.	Office Commercial	University of Florida – Gainesville JF	Provides only values for Cu, Pb, and Zn, with only Total concentrations
18.	Office Commercial	Elm Drive	There were data for all the different constituents but only for Total concentrations
19.	Office Commercial	Apex high School	No data
20.	College Campus	University of New Hampshire	There is only data for Zn and Total concentration in samples

3.7 Due diligence

There were several possible sources of error. These included variables that form part of the study such as: amount of dry days between storms, the varying usage of the parking lot, rainfall intensities, and timing of sampling. Ideally the study should have extended over more than one site and over a longer period, where the data could have been used to reduce the errors that was found during the study or find the significance on the errors. However, this was not possible due to time and funding constraints.

With the metal concentration results it was found that in several cases the dissolved metals were more than the total metals in the same sample taken (As = 38/98 = 39% the dissolved metal concentration was more than the total metals; Cd = 52/98 = 53%; Cu = 50/98 = 51%; Pb = 23/98 =23%; Zn = 57/98 = 61.3%).

The laboratory staff indicated that this could be due to impure nitric acid being used to preserve the metals in the samples. The samples were tested with distilled water with the same amount of nitric acid as with the samples. This showed that the Nitric Acid had traceable amounts of metals. Table 3-6 shows the concentrations of the various elements found in the distilled water after being treated with the impure nitric acid.

Table 3- 6: Blank Nitric Acid Test results

	Cu	Zn	As	Cd	Pb
	µg/l	**µg/l**	**µg/l**	**µg/l**	**µg/l**
Concentration	21.8	46.0	0.21	0.27	0.10

These concentrations were used to adjust the metal results accordingly.

Another probable reason for the higher dissolved concentrations could have been the metals being pushed through by reusing the same filter for two consecutive sample. This possibility was tested, and it was found that even if the sample is filtered with a new or old filter, the same inconsistencies were observed.

Event Mean Concentration (EMC) is used to measure the average reduction in pollutant concentrations for stormwater, formula 3-3 show how EMC is calculated (Erickson, et al., 2013).

$$EMC = \frac{\sum_{i=1}^{n} V_i C_i}{\sum_{i=1}^{n} V_i} \quad (3\text{-}3)$$

V_i = Discharge amount corresponding to sample i

C_i = Pollutant concentration in sample i

i = Sample number

n = Total number of samples

The BMP database provides constituent concentrations in EMC, therefore, the onsite samples had to be converted to EMC. The volume of runoff was calculated using the area of the parking lot and the roofs that contributed to the total volume runoff where the samples were taken. The volume was then calculated by multiplying the area with the gauge reading measured after every sample. For example:

If 3mm rain fell between sample 3 and 4, the volume would be equal to 18600m^2 (area of the parking lot and roofs, see Table 3.7) multiplied with 2mm (gauge reading difference measured between sample 3 and 4), the volume would be 55.8m^3. This was done for each sample taken. It was assumed that all the runoff of the parking lot collected at the one storm drain, it may have been an overestimation.

The EMC for each storm event was then calculated by multiplying the volume of each sample with the corresponding concentration for the metals measured by the CAF. The EMC of all the samples taken per storm event was then summarised and divided by the volume measured during the specific storm event.

$$EMC = \frac{119.87}{303.166} = 0.3954$$

Table 3- 7: EMC Calculation example

Sample number	Sample concentration (µg/L)	Area	Gauge reading – cumulative gauge reading (mm)	Area x gauge reading = volume	$V_i C_i$
1	0.59166	18600	2	37.19836	22.01
2	0.443479	18600	1	18.59918	8.25
3	0.395302	18600	3	55.79754	22.06
4	0.303532	18600	3	55.79754	16.94
5	0.339187	18600	3	55.79754	18.93
6	0.393506	18600	3.7	68.81697	27.08
7	0.424571	18600	0.5	9.29959	3.95
8	0.496714	18600	0	0	0.00
9	0.250201	18600	0.1	1.859918	0.47
10	0.106009	18600	0.1	1.859918	0.20
Total				**303.1666**	**119.87**

The same method was used to calculate the Total, Dissolved and particulate EMC. The particulate concentration was calculated by subtracting the Dissolved from the Total concentrations.

The mass was calculated by using the same method as above, but instead of dividing with the volume at the end, the concentration (µg/L) and the volume (L) was multiplied with each other giving values in µg.

3.8 Statistical evaluation

Two different statistical evaluations were conducted; the first was comparing the different metals from each storm event with each other. For example, As sorted from lowest concentration to highest concentration for the first storm and doing the same for Cd for the same storm event and finding correlation between Cd and As.

Correlation coefficient, or differently known as Pearson Product Moment correlation coefficient, denoted as r, is a method to show the strength of two set of samples with each other. The closer the value is to 1 or -1, the better the linear association between the datasets (Boston University School of Public Health, 2013). Correlation shows how an independent variable is numerically related to the dependent variable, which is denoted as r^2 (Surbhi, 2016).

The second evaluation was the investigation into the correlation between the on-site data EMC values and data from the selected BMP database case studies. The data from both the study site and the BMP database were sorted from smallest value to largest and using the data function in excel correlation analysis were conducted (Excel, 2013).

Chapter 4 Results and Discussion

The results obtained from the laboratory tests described in Chapter 3 are discussed below.

4.1 Traffic on site

The parking area was recently constructed to improve parking on campus. Currently, there are 340 parking bays. Additionally, between the hours of 08:00 and 16:00 during the semester it is often full to over capacity with between 50 and 100 extra cars within the parking area, parking on yellow lines and on the sidewalks. An approach of data capture for different scenario days was followed and the number of cars within the parking lot was counted throughout. The different scenario days were holidays, semester weekdays and weekends, as well as exam periods; this provided a rough estimate of the parking lot usage over the year.

It was found that, during the university holidays the parking area is rarely used, with an average use of approximately 10% during the week and 20% during the weekends. During exams the parking lot is 40% to 70% full, depending on the exam timetable.

4.2 Weather considerations

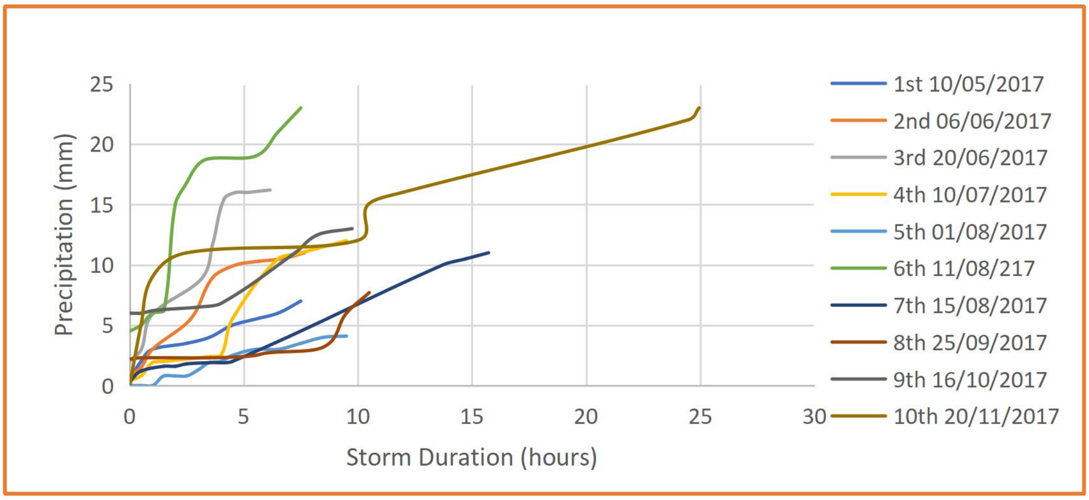


Figure 4- 1: Cumulative precipitation per storm

Figure 4-1 shows the cumulative precipitation of each storm event evaluated during this project. The steeper the slope the higher the flood peaks. As can be seen, rainfall events were inconsistent and had varying storm durations and behaviour. For example, during the sixth storm event a total of 23mm of rain fell, within a period of 7.5 hours. The graph also shows that for the same storm event only 0.2mm fell for two hours, this was between 3h50 and 5h50 in the morning (exact times does not show on the graph).

As seen with the sixth storm event, rain often lapsed for a few hours, only to start up again later during the storm event.

Rainfall measurement during the second term

Rainfall events occurred before the first samples were taken on 10 May 2017. The first sampled storm event was during the 2nd term, therefore the parking lot was mostly in over-full-use during the week. During the first sampled storm event, up to 7mm precipitation was measured. The total rainfall during May was only 10.5mm, therefore there was only one storm event captured in the month of May. The next storm event was not captured, due to incorrect rainfall prediction for the day, 3 June 2017.

The second sampled storm event was during the first day of the second round of exams, on the 6th of June 2017. Therefore, the parking was still in use, but with half of the vehicles normally observed. The total amount of precipitation was measured at 49 mm for the storm event. Here it was predicted that a massive storm was to hit Cape Town and therefore the university was closed for the day. Samples were taken at the beginning of the storm event, for three hours and 40min, with a rain gauge reading of 11mm.

The third sampled storm event, 20 June 2017, was taken after three dry days. There were light rainfall events between the second and third sample, but not enough to get adequate samples for testing. The total rainfall reading for 20 June was 22.5mm. June was the highest rainfall month for 2017, 142.9mm. The samples were taken at the end of the second round of exams, where there were approximately 10 to 15 cars found in the parking lot.

Mid-year holiday

The fourth sampled storm event, 10 July 2017, was taken during the university holidays, therefore only a few cars, as with the third sample, were observed. The rain gauge reading at the end of the storm was 12mm and there were 20 dry days before the sampling day. When looking at the metal concentrations, for example Figure 4.6 unfiltered As, it does not seem as if there was much build-up over the 20-day dry period, there is an overall reduction in As. This can be due to the parking lot not being in high use during the 20-day period.

Third term

The fifth sampled storm event, 1 August 2017, only measured 4.5mm on the gauge, between 08:00 and 17:30. The precipitation stopped for a few hours and started again the next day, measuring a total of 6mm rain over the two-day period. Water quality samples were only taken on the 1st of August. The samples were taken during the third term, where the parking lot was in over use, as with the first sampling day.

For the sixth sampled storm event, 11 August 2017, the first sample was taken at 04:30 the morning, when 4.5mm rain had already fallen. There was a much higher flood peak observed with 21mm in 6.5hours. The contaminants concentration was lower than the previous sampling day. This can possibly indicate the lower the flood peak, the higher the concentration loading in the parking area. The parking lot was also in over-use during this period.

The seventh sampled storm event occurred over two days, 15-16 August 2017, with four dry days before the storm event. The samples were also taken during the third term with the parking lot in full use and the total precipitation for the two days was 69.2 mm. The highest precipitation storm event recorded for 2017.

Fourth term

The last two sampling storm events were taken during the dry season, with more dry days between rainfall events. Only nine samples were taken the last sampling days, 16 October and 20 November 2017.

As can be seen in Figure 4-2, the storms had different precipitation volumes, intensities and durations. Each rainfall event influences the concentration of each sample, as discussed in further detail below.

4.3 Stormwater pollutants

Stormwater pollution can be categorised due to two stages, namely pollutant build-up and pollutant wash-off (Vaze & Chiew, 2002) . The build-up occurs during the dry periods, whereas the wash-off occurs during the wet periods (Vaze & Chiew, 2002). A study conducted in Melbourne Australia over a 36-day period indicated that pollution build-up occurs rather quickly after a rainfall event, but after a few dry days the build-up reduces (Vaze & Chiew, 2002).

The different pollutants found in stormwater is dependent on the runoff area environment, such as the composition of surrounding infrastructure (roofs, roads, etc.) and human activities. In areas that are underdeveloped the stormwater typically infiltrates the ground. A study conducted by various researchers from institutions around Europe (see Eriksson et al., 2007) identified 25 typical stormwater runoff pollutant parameters. Among these were organic and particulate materials, pH, nutrients, different metals (Cd, Cr, Cu, Ni, Pb, Pt, Zn), Polycyclic Aromic Hydrocarbons (PAHs), Herbicides, and other industrial runoff compounds. Additionally, it has been found that constituent concentrations changed throughout every storm event. The average reduction in pollutant concentration is represented by the Event Mean Concentration (EMC) as discussed in Chapter 3 (Eriksson, et al., 2007) . The data obtained from the CAF was compared with the BMP database, to see if there is a correlation between the data found on-site in Stellenbosch and different land uses found in Northern America.

The "first flush" phenomenon

An important phenomenon in stormwater runoff quality is that of "first flush". This has generally been found to be the highest pollutant concentration load for any storm or group of storms ((Stenstrom & Kayhanian, 2005), (Stenstrom & Kayhanian, 2005)). It has been defined as:

"The discharge of a larger mass or higher concentration in the early part of a storm relative to the latter part of the storm. The term can be applied to any contaminant. The magnitude of the first flush will depend on site specific conditions, but the term first flush is applicable." (Stenstrom & Kayhanian, 2005)

or

"The discharge of a larger mass or higher concentration of the first storm or first few storms of a rainy season, relative to storms later in the season." (Stenstrom & Kayhanian, 2005)

During the sampling in this research, it was found that the first definition was not always applicable to this specific study site. As shown in Figure 4-2 there was a significant difference in floating debris in the containers, but the sample in the container on the right was taken 13 hours later than the samples in the containers on the left.

NOTE: all the sample bottles in the figures were full (750ml)

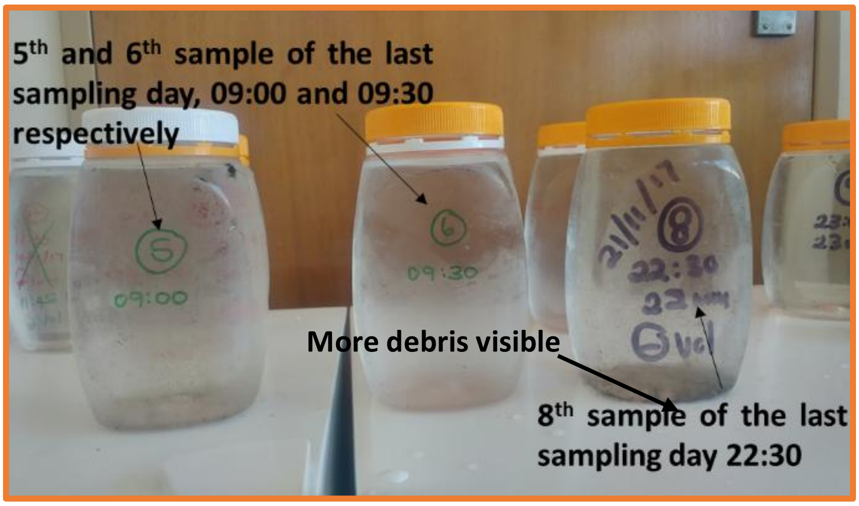


Figure 4- 2: Sediment concentration over time

Figure 4-3 shows where the first flush principle can be applied for a specific storm event, the samples were taken from right to left, where there was a clear reduction in turbidity in the water, where the sample on the left shows completely clear water, just an hour after the storm started.

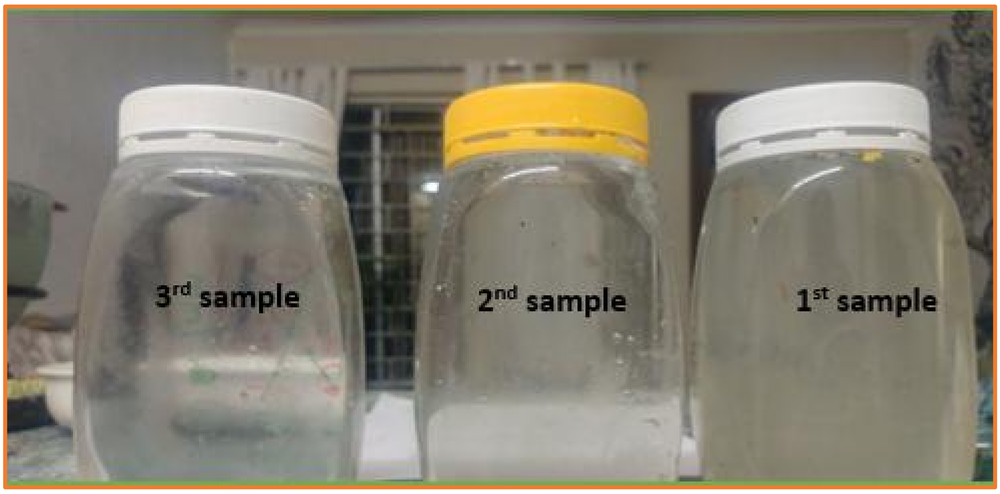


Figure 4- 3: Reduction in turbidity after "first flush"

4.4 Parking Lot water quality test results

The results were categorised by the different sampling dates and shows the concentration index with the use of box-and-whisker diagrams. An example of this is illustrated in Figure 4-4 below. Specifically, the 25th and 75th percentile, the median, and the highest and lowest concentration of each storm event are indicated. During the first eight storm events there were 10 samples taken, whilst on the last two storm events there was only enough time for nine samples. The y-axis indicates the concentration of metals in the water, micrograms per litre.

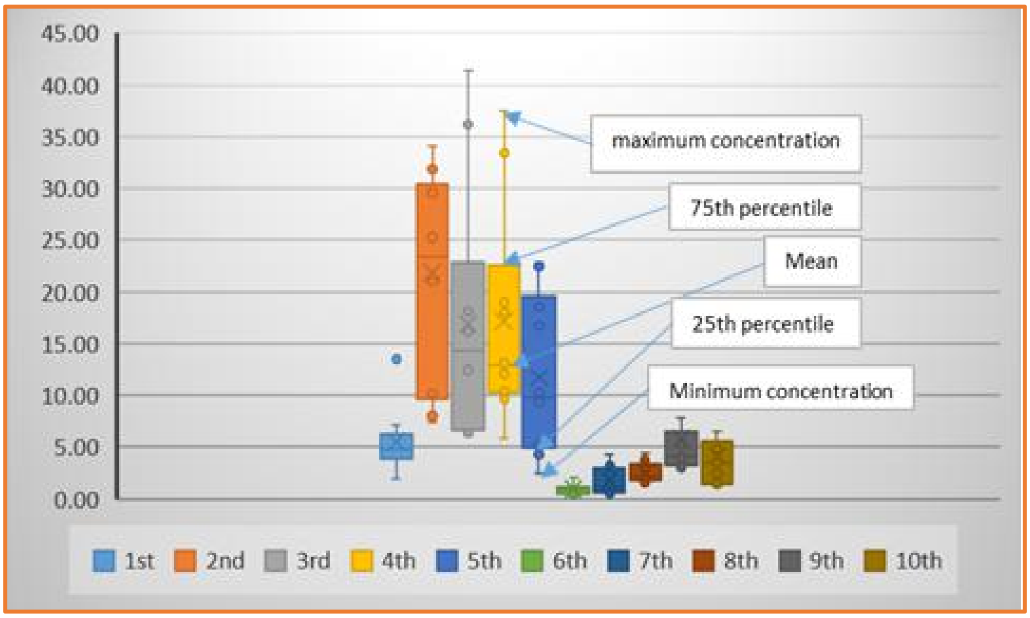


Figure 4- 4: Box-and-Whisker diagram

The results were obtained from the study site described in Chapter 3: Methodology, Parking lot of the Stellenbosch Engineering faculty. The different constituents that were tested for was: As, Cd, Cu, Pb, Zn, TSS, ISS and VSS. The highest concentration of each constituent in a storm event was compared to SANS 241, which is the South African Standards for drinking water. This was done to check the quality of water for harvesting purposes and preliminary design in Chapter 5. The concentration limit of each element in drinking water is summarised in Table 4-1 below. The raw on-site data can be found in Appendix A.

Table 4- 1: SANS 241 Drinking Water Quality Standards (SANS 241, 2015)

Element	Risk	Limit
As	Health	≤10µg/L
Cd	Health	≤3µg/L
Cu	Health	≤2000µg/L
Pb	Health	≤10µg/L
Zn	Aesthetic	≤5mg/L
TSS	Aesthetic	≤1200 mg/L
ISS	-	-
VSS	-	-

4.4.1 Arsenic (As)

In its natural form Arsenic (As) is a metalloid (element with properties between that of metals and non-metals) which is found in the Earth's crust, soil, rock, air and in water. In combination with other elements Arsenic can be found in many different forms, either inorganic (not containing carbon), or organic (containing carbon). Arsenic is not soluble in water, but when combined with other elements it can be soluble, depending on the surrounding acidity, and the presence of other chemicals. Arsenic exposure found in water over a long period increases the risks of skin, lung, bladder and kidney cancer, as well as skin pigmentation or hyperkeratosis. It has been shown that As may have a positive effect on plant growth, or the plants have adapted to the arsenic in the soil and have little to no side-effects as a result thereof (Gomez-Caminero, et al., 2001).

The SANS 241 limit concentration for arsenic in drinking water is under 10 µg/L. Figure 4-5 shows the highest total As onsite data for each storm event compared with the allowable SANS 241 limit of As. The values indicate that the As in the stormwater runoff is of drinkable quality, where the concentrations were on average 93.3% lower than SANS241 limit.

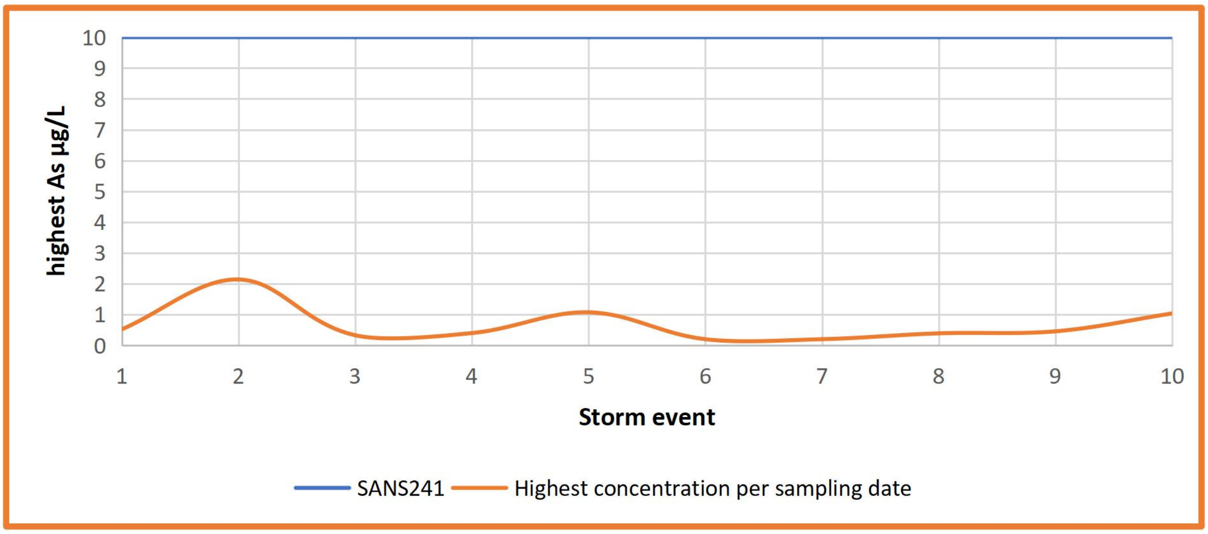


Figure 4- 5: SANS 241 limit for As

<u>Unfiltered (total) As</u>

Figure 4-6 provides the unfiltered (Total) Arsenic sample concentrations of all the samples taken over the sampling period. The second storm event shows an increase in As concentration from the first storm event, this can be due to the higher flood peak calculated on the second sampling date. The decrease in the sample concentrations can be due to less dry days between sampling dates. The seasonal first flush could have loosened the As during the first storm and flushed the As away during the second. The highest total concentration of As observed during the second storm event, second sample, provided a concentration of 2.14 µg/L, half an hour after the first sample was taken. The lowest concentration of As observed was 0.1 µg/L, during the sixth sample taken on the fifth sampling day. During the fifth sample a very low intensity of precipitation was recorded. Little obvious variation was observed on the sixth and seventh storm events, where all the concentrations was recorded as >0.2 µg/L. The lack in variation can be due to calibration mistakes at the CAF before testing. The calibration must be very precise due to working with values smaller than 1µg/L.

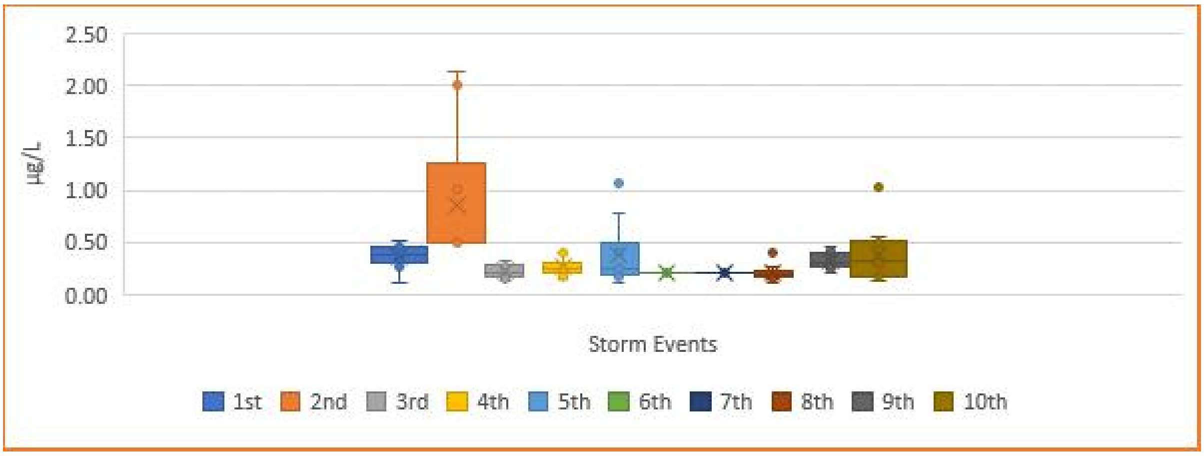


Figure 4- 6: On-site unfiltered As

Filtered (Dissolved) As

Figure 4-7 shows the dissolved As concentrations of the data obtained from the test site. The highest concentration, 1.08µg/L, was recorded during first sample on the second storm event day. The lowest concentration, 0.1µg/L, was taken during ninth sample of the fifth storm event. It was also observed that there were higher concentrations of dissolved As than total As during different storm events days. This can be seen in the raw data found in Appendix A, where up to 39% of the samples shows this occurrence. As stated before, measurement of such small concentrations are open to mistakes in equipment calibration and it was therefore concluded that the arsenic concentrations mostly consisted of dissolved matter in these cases.

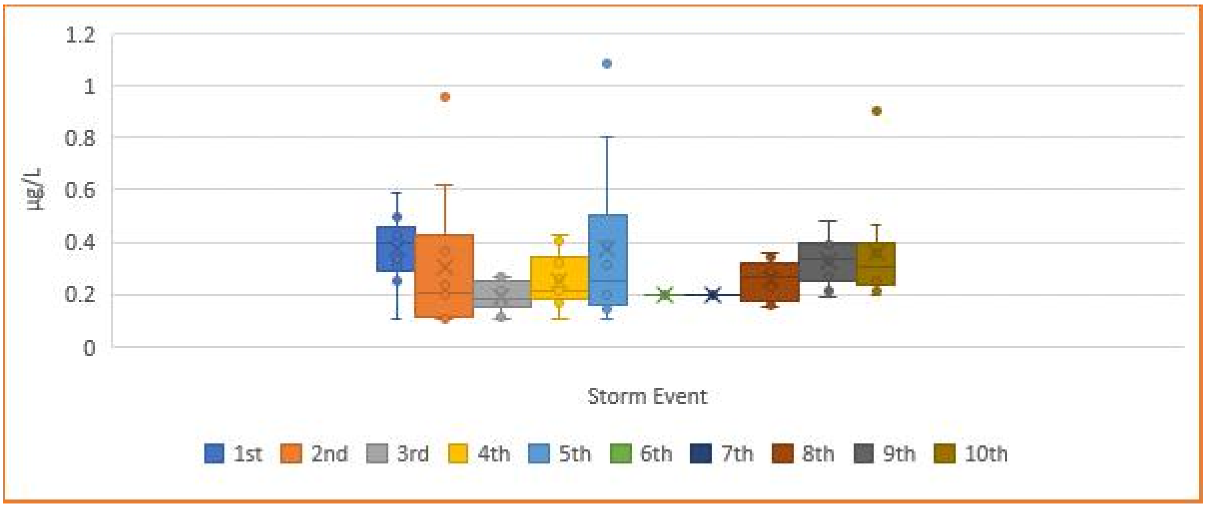


Figure 4- 7: On-site filtered As

Particulate As

Figure 4-8 shows the particulate As found throughout all the storm events. The second storm event provided the highest concentration of particulate As. This indicated that with the low intensity rainfall of the first storm event, the As was loosened, and washed off during the higher intensity second storm event.

From the figure it was found that the second storm event provided a higher range of particulate As, which varied between 1.52µg/L and 0.27µg/L. Also, with the last two storm events there was a clear increase of particulate As concentrations. This indicates that with more dry days between storm events a higher concentration of particulate As was washed off during a storm.

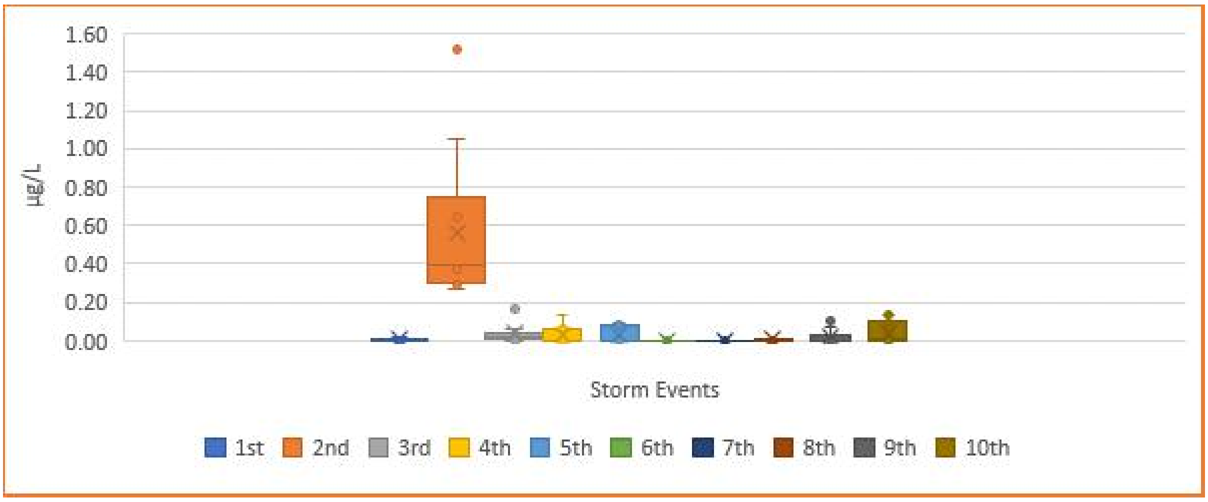


Figure 4- 8: On-site particulate As

Mass of As

The highest mass of As was observed during the 10th storm at the second last sample taken that day, 54.8 µg, based on the volume and the concentration of As in the sample. All the masses for As can be found in Appendix A.

4.4.2 Cadmium (Cd)

Cd is a very soft metal, with a silver-white shine and a bluish tinge, which can be cut with a knife, and discolours when exposed to air. The element is primarily found in the Earth's crust or enters the environment through the ground from pesticides and manures. Cd is mainly used in batteries, pigments, coatings, plating, and stabilizers for plastics (Lenntech, n.d.)

Indications of Cd poisoning can be Diarrhoea, stomach pains, sever vomiting, damages to the filtering mechanisms in the kidneys, reproductive failure to infertility, bone fracturing, damage to the immune system, psychological disorders, and cancer (Lenntech, n.d.)

The threshold damage to health for Cd in drinking water is anything above 3 µg/L in accordance with SANS 241. Figure 4-9 shows the highest onsite total concentration of Cd for each storm event, this was compared with the allowable SANS 241 limit of Cd in potable water. The values indicate that the Cd concentration in the stormwater runoff was of drinkable quality. Overall, the average Cd concentration was 75% lower than the SANS 241 limit.

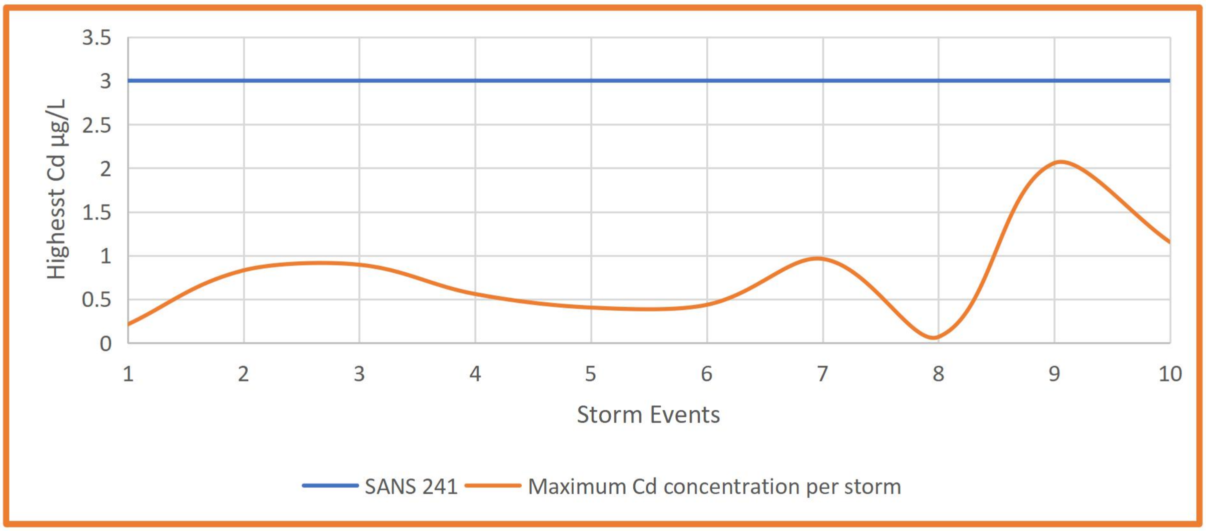


Figure 4- 9: SANS limit for Cd

Unfiltered (total) Cd

Figure 4-10 illustrates the total Cd concentrations recorded during the sampling period. There were two sampling days, which provided a wider range of Cd concentration, but this was due to very high outliers on the ninth and tenth storm event. The possible reason for these high outliers can be due to more dry days between storms, and high use of the parking lot.

Taking out the high outliers the highest range recorded was on the seventh storm event, with the lowest at 0.1 µg/L, and the highest 0.96µg/L. The precipitation during the seventh storm event was consistent throughout the storm. Therefore, with more consistent rainfall a greater range of Cd concentrations was observed.

Overall the highest concentration observed was during the ninth storm event, 2.057µg/L, during the third last sample taken that day. There were approximately 3 hours of no rain, and within half an hour 4.2mm of rain fell, providing a higher intensity of rain over a short period. This sample's concentration was up to 88% higher than the average of the all the other samples taken during the storm event. The lowest concentration was observed during third sample on the tenth storm event, with a value of 0.01µg/L. But, the second highest outlier was also observed during the tenth storm with a concentration of 1.15µg/L during the last sample taken that day.

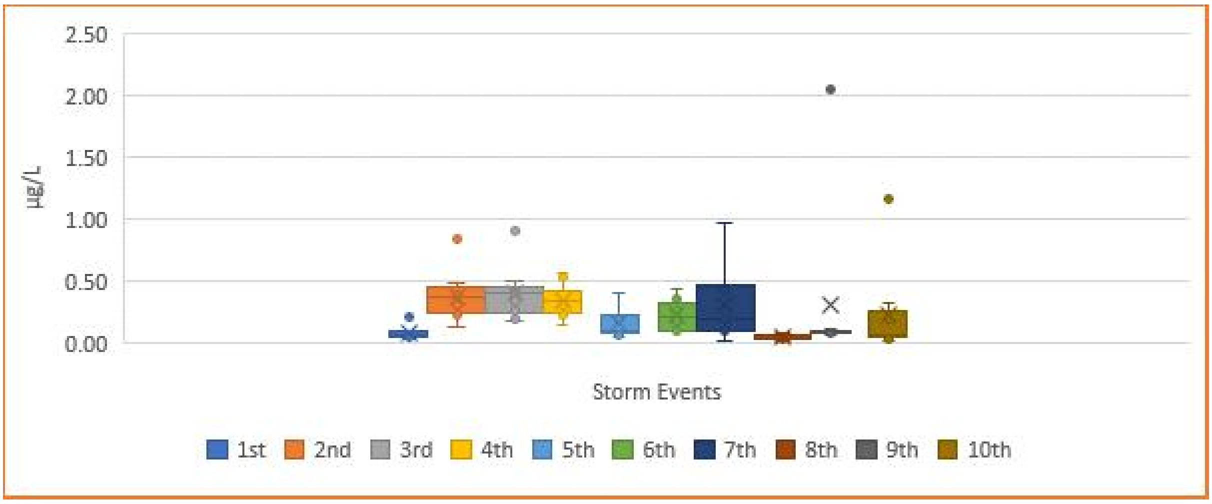


Figure 4- 10: On-site unfiltered Cd

<u>Filtered (dissolved) Cd</u>

Figure 4-11 shows the dissolved (filtered) Cd concentrations during the sampling period. The highest concentration, 1.14µg/L, was observed during the eight sample of the tenth storm event. During the 10^{th} storm event the highest precipitation was recorded over the longest precipitation period. During this event a sudden increase in rainfall intensity between the last two samples was observed. There were up to 20 dry days before the 10^{th} rainfall event. The lowest concentration of 0.02µg/L was recorded during the second sample taken on the eight-storm event. There was a lower intensity rainfall on the eight-storm event, and 21 dry days before the storm.

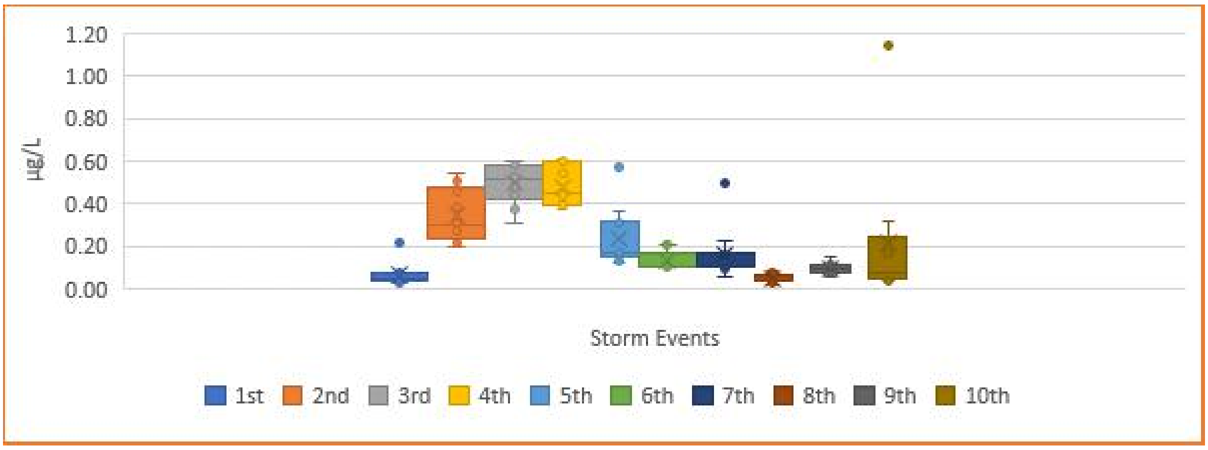


Figure 4- 11: On-site filtered Cd

Particulate Cd

Figure 4-12 shows the particulate Cd concentrations. The ninth sampling day shows an outlier of 1.19µg/L recorded during the seventh sample taken. The seventh storm event shows the greatest range of particulate Cd. The precipitation during the seventh storm event was gradual throughout the storm event, two weeks within the second semester, with only three dry days between the sixth and seventh storm event. The lowest concentration was 0µg/L, where no particulate Cd was present.

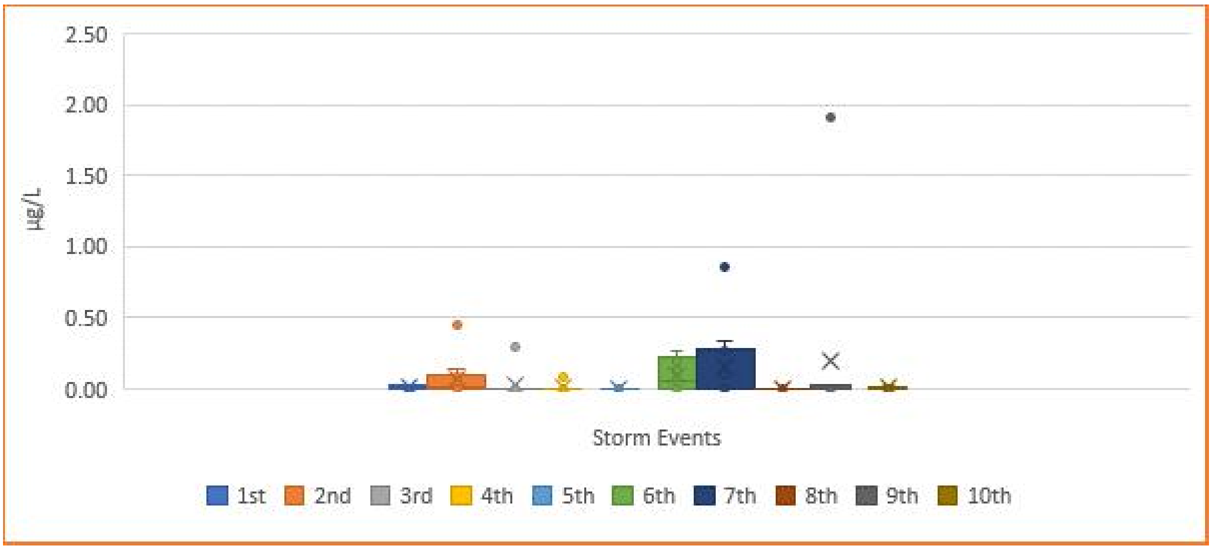


Figure 4- 12: On-site particulate Cd

Mass of Cd

The highest mass recorded during the sampling period was during the 9th storm event, 160.7 µg. All the mass concentration can be found in Appendix A.

4.4.3 Copper (Cu)

Cu is a reddish metal that reflects orange and red light with a 'face-cantered cubic crystalline structure' (Royal Society of Chemistry, 2017) . Cu is a very good conductor, both in heat and electricity and is a soft ductile element (Royal Society of Chemistry, 2017) . Cu is mainly used in electrical equipment and in construction of roofing and plumbing.

Due to the increase in usage of Cu in the industry and agriculture, an increase of Cu in the environment is found. During the combustion of fossil-fuels Cu is released into the atmosphere and stays in the air until it starts to rain, after it ends up in the soils, and stormwater (Lenntech, 2016) Cu can also be released into the environment by wind, decaying of vegetation, forest fires and sea spray. Human activities include mining, wood burning, metal and phosphate fertiliser production. Soluble Cu threatens human health, due to the compounds ability to bind to water, sediment and soil, these compounds are mainly found in agricultural lands (Anon., 2017).

The accepted drinkable water quality level in South Africa for Cu is between zero and 2 mg/L (CSIR Environmental Services, 1996) . Figure 4-13 shows the health limit of Cu compared with the highest concentration of Cu for every storm event. The Cu concentration in the samples were much lower than the health limit. Therefore, Cu in the stormwater did not pose any risk for consumption.

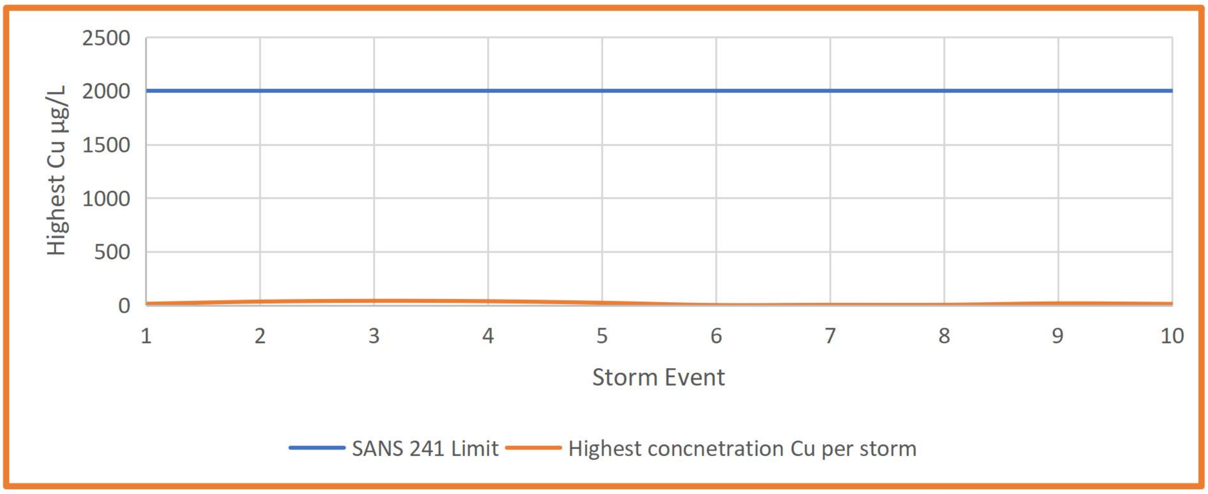


Figure 4- 13: SANS 241 limit for Cu

Unfiltered (total) Cu

Figure 4-14 shows the concentration of Cu over the sampling period. The second sampling date shows a large increase in Cu from the first storm event, where the third, fourth, and fifth shows a slow decrease in Cu concentrations. The sixth sample shows the lowest overall concentration throughout the sampling period. The highest concentration of Cu observed was 41.36 µg/L on the third storm event, there were only three dry days between the second and third storm event. A very low flood intensity was recorded during the third storm, which indicates the lower the storm intensity the higher the Cu concentration. The lowest concentration, 0.22µg/L, was recorded during the sixth storm event, with the highest storm intensity. During the sixth storm event 23mm precipitation was recorded within a seven-and-a-half-hour period. This indicates that the higher the intensity of the storm the lower the concentration of Cu was.

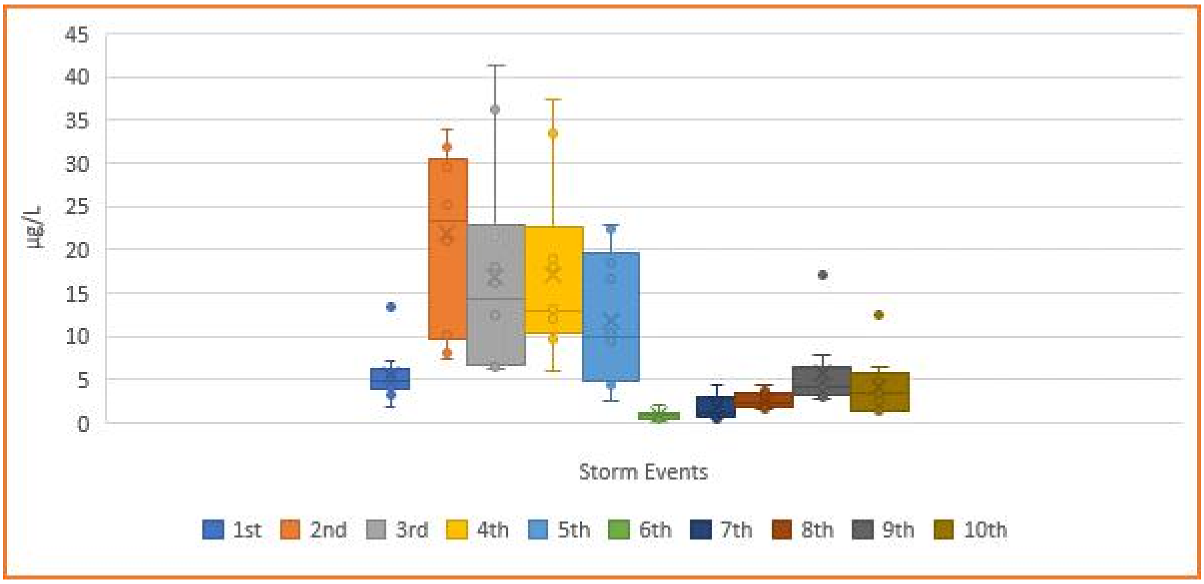


Figure 4- 14: On-site unfiltered Cu

Filtered (dissolved) Cu

Figure 4-15 shows the dissolved Cu concentrations of the samples taken throughout the sampling period. The fourth sample provided the highest concentration of Cu, 38.63µg/L, with a gauge reading of almost nothing after an hour of the storm, with a very low flow that filled the sample bottle, it was like mist rain. Therefore, a low intensity precipitation and 20 dry days before the storm provided the highest concentration of dissolved Cu.

This indicated that during the dry days there was a clear build-up of dissolved Cu, where the use of the parking lot also contributed to the build-up, where it was at full capacity for the 20-day dry period. The lowest dissolved concentration, 0.13µg/L, was taken on the sixth storm event, during the sixth sample taken. The sample was taken during the highest peak flow storm day, after two and half hours with a gauge reading of 16.8mm. This indicates that the harder the rainfall the quicker the dissolved Cu concentration decreased on the parking lot.

The dissolved and total Cu shows the same trend in higher and lower concentrations in the water, with higher intensity rainfall the lower the Cu concentration and the lower the rainfall intensity the higher the concentration of Cu.

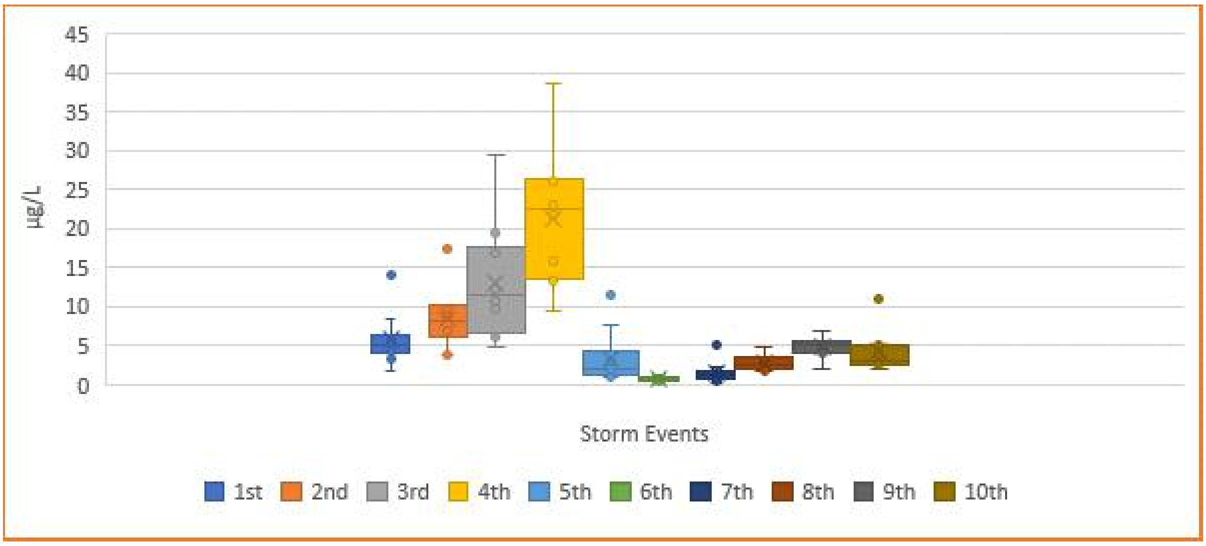


Figure 4- 15: On-site filtered Cu

Particulate Cu

The particulate Cu concentration can be seen in Figure 4-16. The particulate Cu shows the same concentration trend as with the Total and Dissolved Cu concentration. Here the highest particulate Cu was recorded during the third storm event, 26.256µg/L, at the seventh sample taken that day.

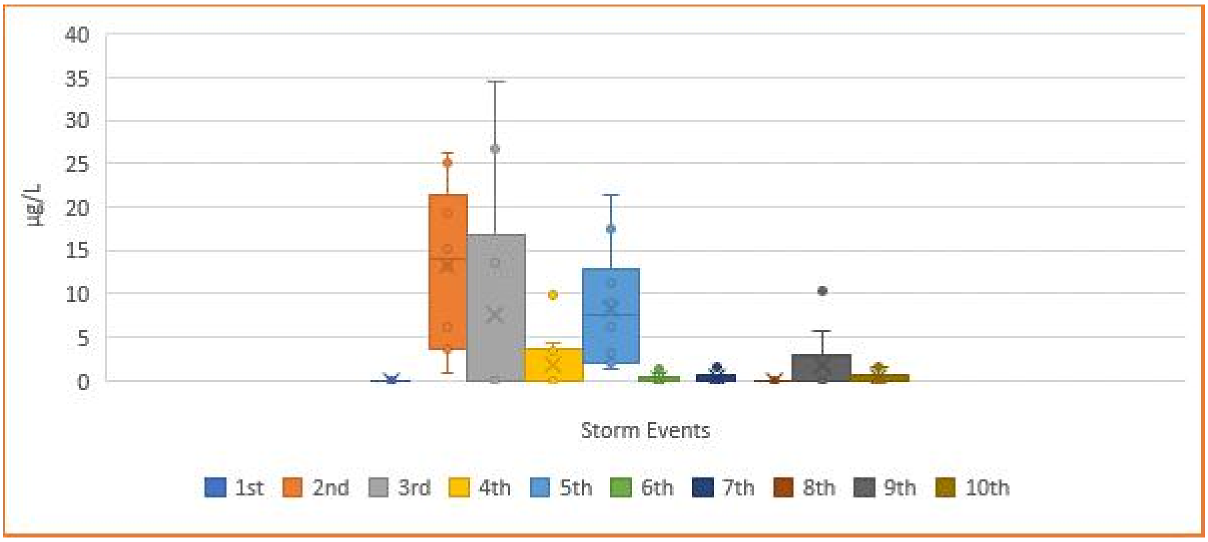


Figure 4- 16: On-site particulate Cu

Mass of Cu

The highest amount of Cu recorded over the sampling period was 3.1 mg, during the fourth storm event. All the masses of Cu can be found in Appendix A.

4.4.4 Lead (Pb)

Lead is a soft, flexible, ductile, blue-white glossy metal, with a low conductivity for electricity, and a very high resistance against corrosion. This metal is one of the final products of naturally occurring radioactive elements, where some petrol still contains tetraethyl lead, but due to the environmental effects it is being phased out. Lead can be found in many forms. It can contaminate food as well as most liquids that humans drink. Up to 65% of the lead humans take in is due to food that is contaminated with lead. Up to 20% of the water humans drink can be contaminated with lead, where the rest is found in the air. Lead poisoning can cause various health problems, such as: disruption of the biosynthesis of haemoglobin and anaemia; increasing blood pressure; damage to the kidney, brain, and nervous system, miscarriages; decrease in sperm count, learning disabilities in children and changes to children's behaviour such as aggression, hyperactivity and impulsiveness. One very detrimental effect on the environment caused by lead is the bioaccumulation in organisms found in the water and soil (Lenntech, 2016). Additionally, chronic lead poisoning is hard to detect before it becomes a deadly (Lenntech, 2016).

The targeted water quality is between 0 to 10 µg/L in accordance with SANS 241. Figure 4-17 shows the health limit for lead compared to the highest concentration of Pb found for each storm event. As can be seen in the graph the concentration of Pb was higher than the SANS 241 limit for most of the storm events. The 10th storm event provided a concentration of 319 µg/L (not shown in the graph due to graph scale).

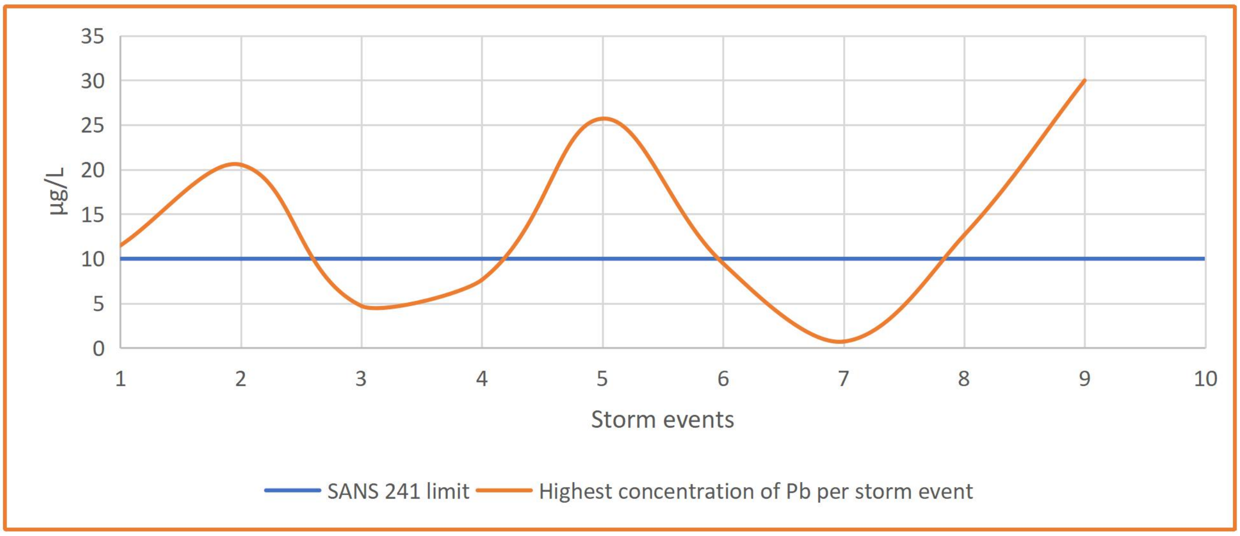


Figure 4- 17: SANS 241 limit for Pb

If not considering the high concentration recorded on the tenth storm event, the Pb poses a major threat, however the bio-retention garden designed in Chapter 5 may be efficient enough to alleviate the amount of Pb in the water. Before any filtration is done, the water is not fit for human consumption.

Unfiltered (total) Pb

Figure 4-18 shows total Pb concentrations found during the sampling period. On average the samples are 97.4% lower than the high outlier concentration of 318.63µg/L recorded during the tenth storm. The tenth storm had an 8hours and 45minutes build-up time between the eighth and ninth sample, due to rainfall intermission. Possibly this reading could have been due to a singular lead containing element coming down the drain, the source of which is unknown.

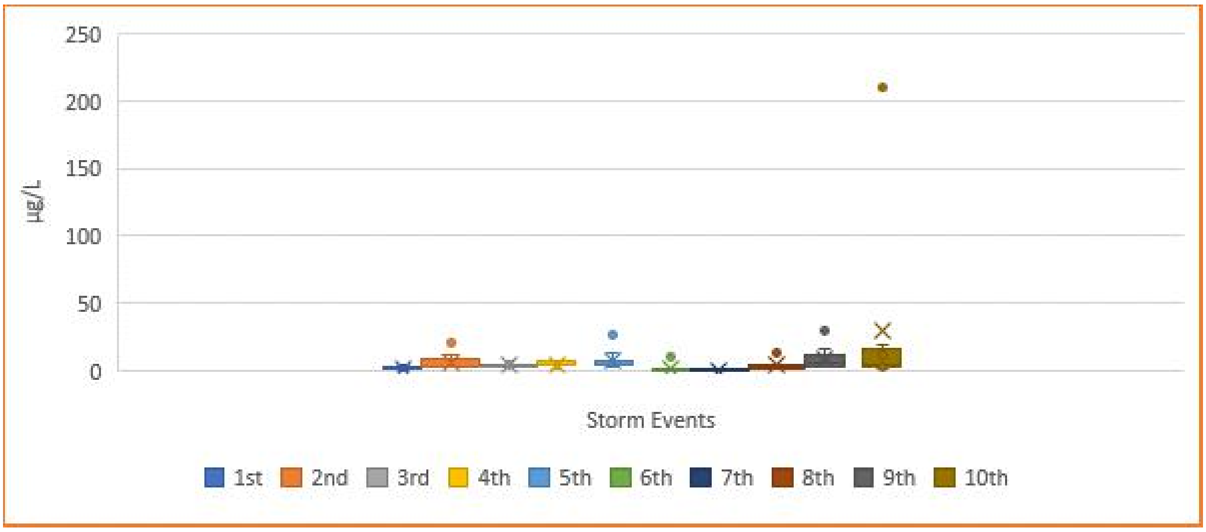


Figure 4- 18: On-site unfiltered Pb

Figure 4-19 provides the graph of total Pb without the tenth storm event with the high outlier. The ninth sample now provides the highest concentration value of 29.988µg/L. The lowest concentration of Pb observed, 0.11µg/L, was captured during the second sample of the seventh storm event. The seventh storm event was 15 August 2017, with four dry days before the storm. These samples were taken over a two-day period.

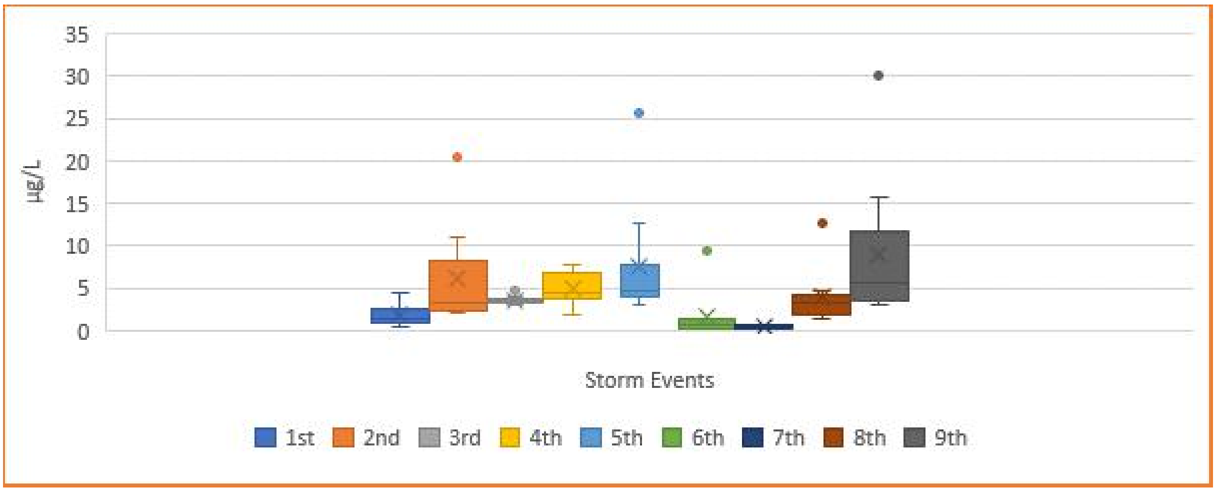


Figure 4- 19: On-site Pb without 10th sample

Filtered (dissolved) Pb

Figure 4-20 shows the dissolved concentrations of Pb. As with the total concentrations main outlier is found during the tenth storm event. The outlier was measured at 210.79µg/L. The lowest concentration measured, 0.18µg/L, during second sample of the seventh storm event, which was found to be higher than the lowest concentration for total Pb concentration. Without the tenth storm event the highest concentration of Pb was 29.88 µg/L.

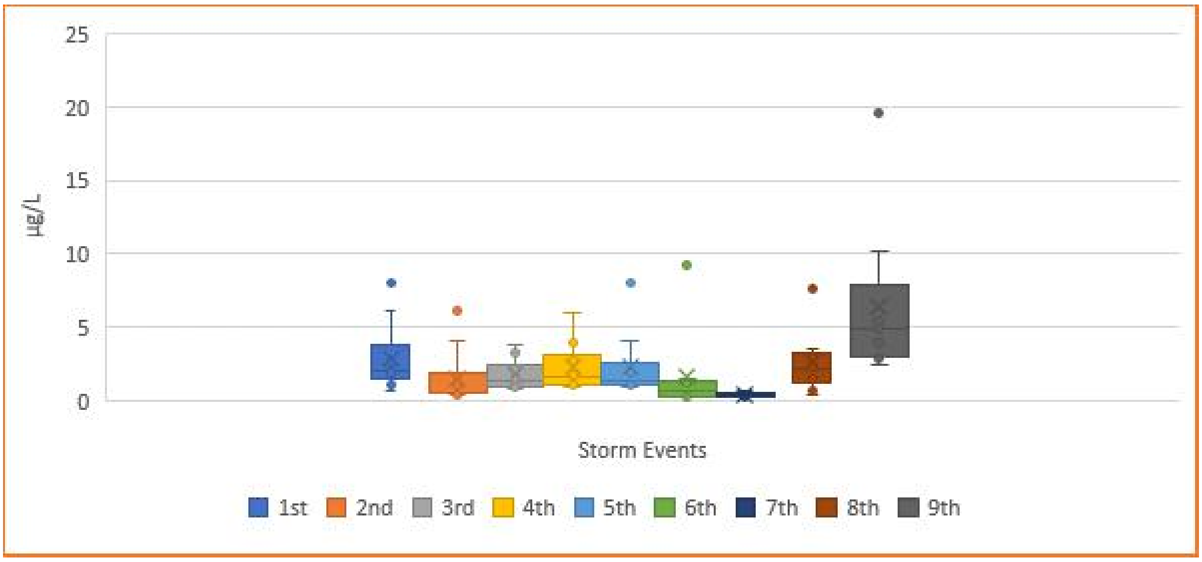


Figure 4- 20: On-site filtered Pb without 10th sample

Particulate Pb

Figure 4-21 shows that the particulate Pb during the tenth storm event was also high, 107.84 µg/L, which was calculated to 35mg of Pb.

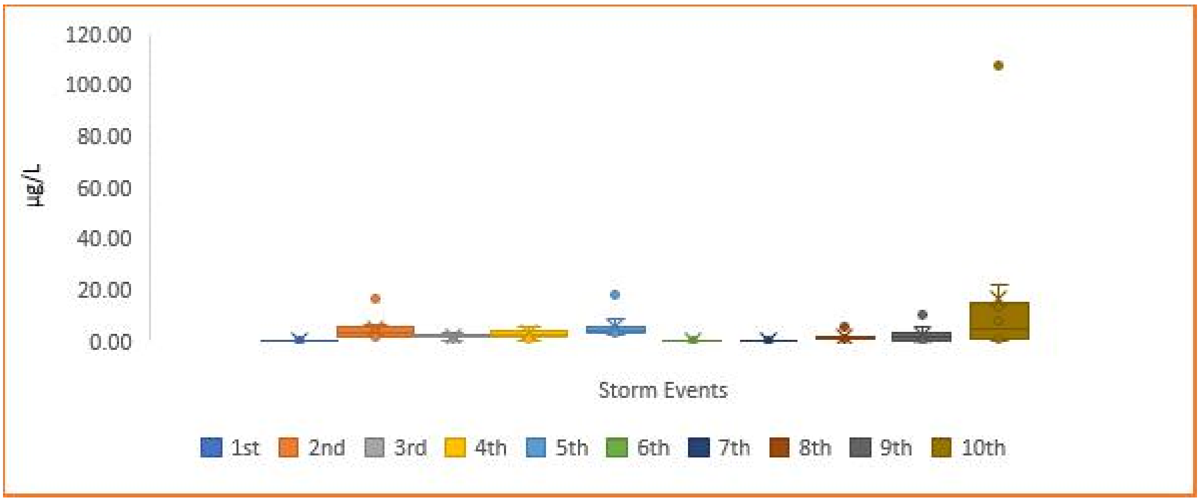


Figure 4- 21: On-site particulate Pb

Mass of Pb

The highest amount of Pb recorded over the sampling period was 35.56 mg, during the tenth storm event. All the masses of Pb can be found in Appendix A.

4.4.5 Zinc (Zn)

Zinc is a brittle and sparkly element at room temperature, but when heated to 150°C it becomes flexible and ductile. Zinc can easily react with non-metals and when diluted in acids it releases hydrogen. Zinc is primarily used in batteries, galvanised steel applications (roofing and gutters) and can also be found in coins, vehicles, paint and as an activator for the rubber industry. The increase is pollution levels is mainly due to an increase in mining, where it is used in coal, waste combustion and steel processing, as well as due to wastewater treatment plants not purifying their water to satisfactory levels. Zinc is important to human growth and health and the lack of zinc can cause loss of appetite, taste or smell; birth defects and slower healing of sores and wounds. Humans can assimilate a lot of zinc, but if too much is accumulated, it can cause vomiting, skin irritation, stomach cramps or anaemia. Higher concentrations can cause disturbance in protein metabolism, damaging effects on the pancreas, arteriosclerosis and the combination of chloride and zinc can cause respiratory disorders (Lenntech, 2016).

The acceptable SANS 241 limit for Zn in drinking water is 5mg/L. Figure 4-22 shows the highest concentration of Zn from each storm event compared with SANS 241 standard. As can be seen the overall Zn concentration in the samples were much lower than the health limit, calculated to be up to 79.8% lower.

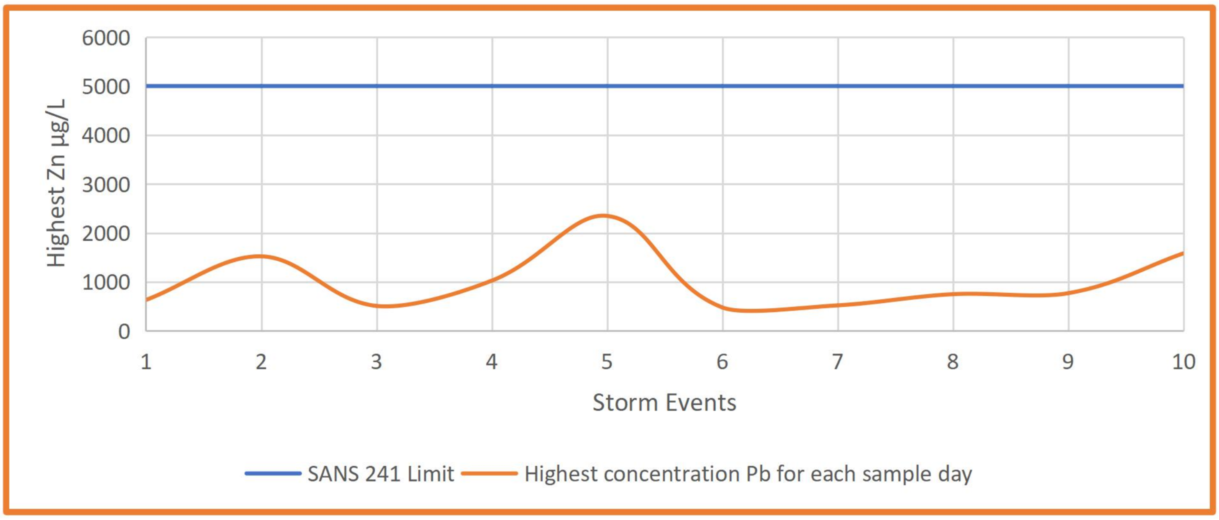


Figure 4- 22: SANS 241 limit for Zn

Unfiltered (total) Zn

Figure 4-23 provided the total concentration of Zn throughout the sampling period. The tenth sample showed the highest concentration variation with highest being 1583.47 µg/L, at the first sample, and the lowest 150.24µg/L, at the third sample. This indicates that the Zn concentration reduced rapidly when a storm event occurred. Overall, the highest concentration observed was during the fifth storm event, 2348µg/L. Here, the intensity of the flood peak was low - during the first two samples almost zero mm of rain was read from the gauge.

The lowest concentration of Zn was recorded on the sixth storm event at 128 µg/L. The intensity of the storm was high, with the first reading already at 5mm, and two hours later the gauge reading was at 15mm.

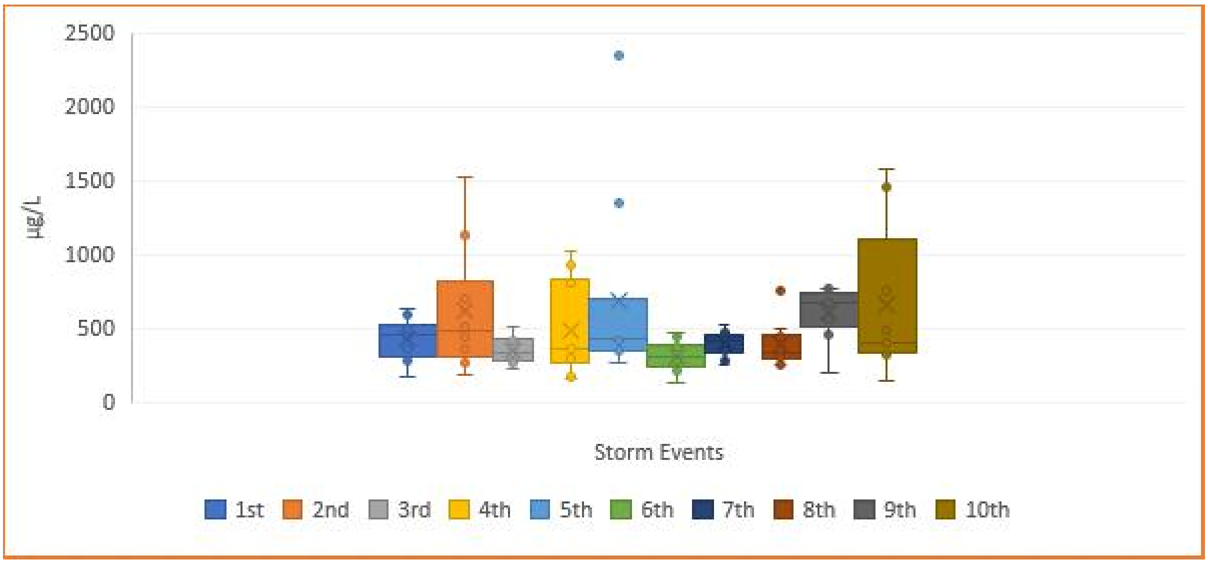


Figure 4- 23: On-site unfiltered Zn

Filtered (dissolved) Zn

Figure 4-24 provides the dissolved concentrations of Zn throughout the sampling period. The highest concentration observed was 2351µg/L, during the fifth storm event. This storm had a low intensity flow. This is opposite of what is observed with the total Zn concentrations. The lowest concentration of Zn was observed during the sixth storm at 128 µg/L, with a high intensity rainfall.

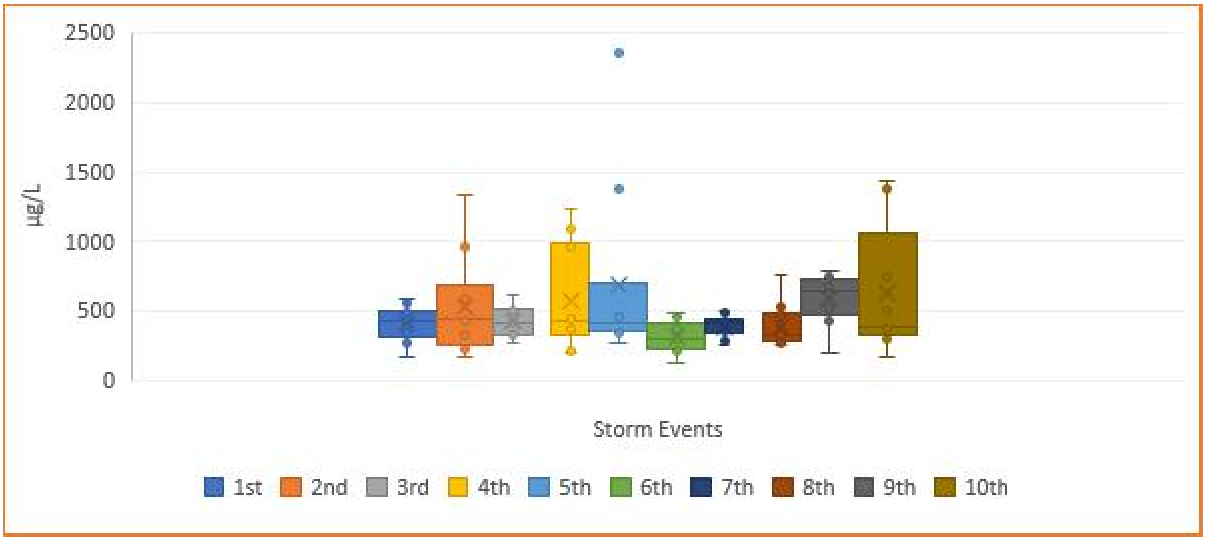


Figure 4- 24: On-site filtered Zn

Particulate Zn

The particulate Zn concentrations for the sampling period can be seen in Figure 4-25. The highest particulate Zn concentration was recorded on the sixth storm event. The highest intensity rainfall was also recorded during the sixth storm event. The highest variation in particulate Zn was recorded during the second storm event, between 16 and 183µg/L. The results show that when the intensity of the storm was high the particulate Zn concentrations were higher, which was also seen for the total Zn.

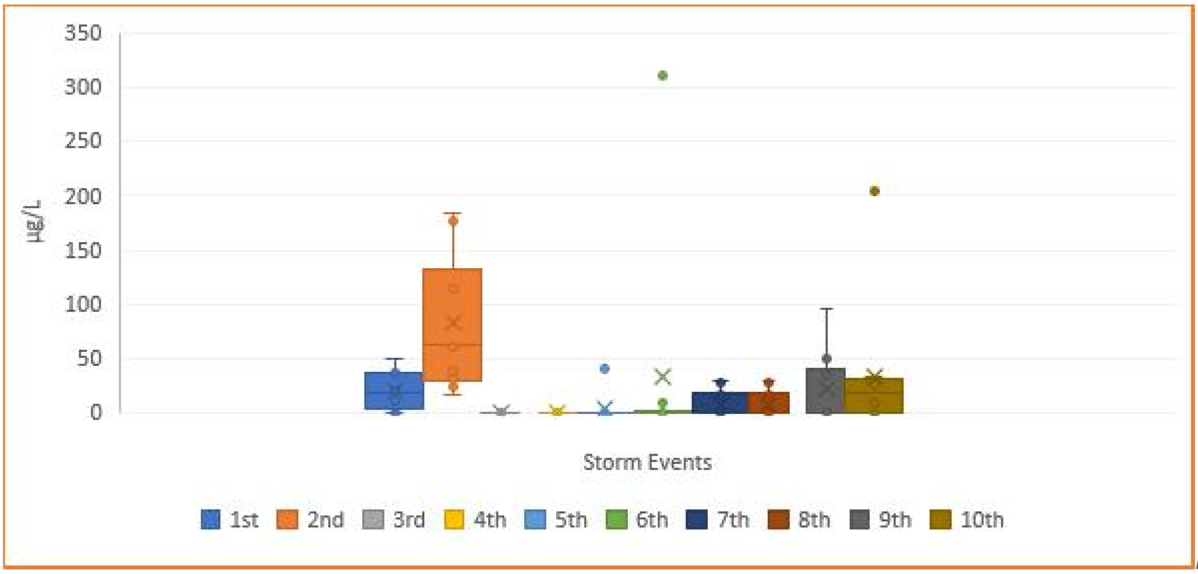


Figure 4- 25: On-site particulate Zn

Mass of Zn

The highest mass of Zn, 162.56mg, was recorded on the tenth storm event, during the second last sample taken that day. All the masses of Zn can be found in Appendix A.

4.4.6 Total Suspended Solids (TSS)

The masses were calculated using formula 3-1. Using the crucibles, it was found that TSS concentrations were negative in many cases (final masses after drying were less than crucible masses), which might be due to moisture absorption or reduction of the crucible weight during the oven heating process. Therefore, the filter paper without the crucible was also weighed, which provided less negative TSS values.

According to the manual of the scale used in the laboratory, Zeta Series Balances scale, the weight reading can vary by 0.001mg, for a single weight range (SCIENTECH, n.d.) . This means that after every time the filters were weighed there could have been 0.001mg error from the actual weight. Note that the error could have occurred before filtering the samples, and after being in the oven, this means a weight error of 0.002mg was possibly applicable to the negative values of TSS.

Figure 4-26 below shows the concentration of TSS for the last five storm events. The first four storm events samples were inconclusive, as the samples were tested with a sampling volume of 100ml and did not provide concentrations values of TSS equal to zero or above. Therefore, the sample sizes were adjusted by using between 350ml to 400ml. The method was provided by the Standard Methods manual (Rice, et al., 2012) . The highest concentration of TSS was found during the 10th storm event at 0.536mg, which was during a high intensity storm and high flow rate.

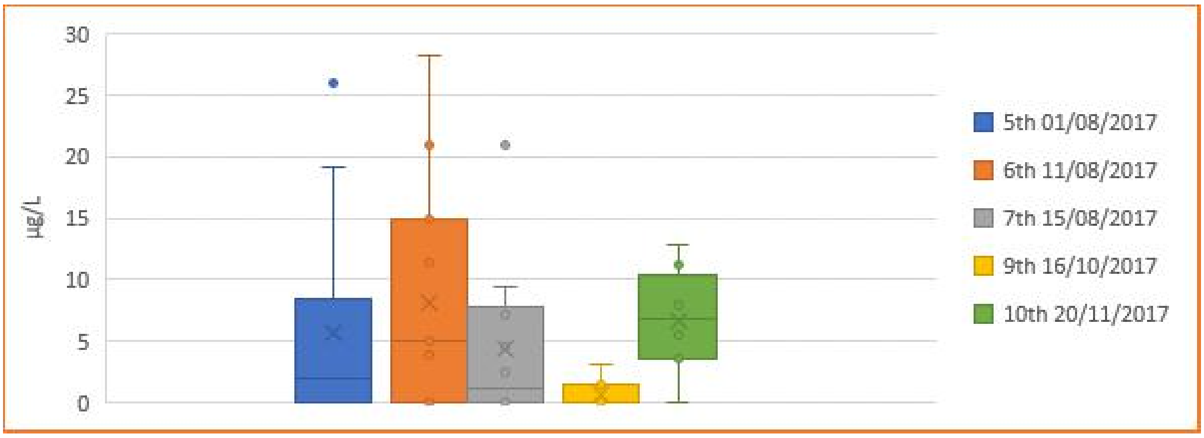


Figure 4- 26: On-site TSS results

4.4.7 Volatile Suspended Solids (VSS)

As with TSS an error could have occurred during weighing of the filter paper, and another 0.001mg was added to the already 0.002mg for weighing the filter after ignition in the furnace. This was only added to samples with a negative VSS value to evaluate whether the result was within error range. In these cases, it was assumed that the VSS concentrations were close to 0.

Figure 4-27 provides VSS for the fifth, sixth and seventh storm events, the other values were inconclusive. The highest concentration of VSS was observed during the sixth storm event at 60 µg/L, which was the highest flood peak recorded during the sampling period. This low value shows the difficulty with using gravimetric methods for measurement since the method is not accurate for low masses.

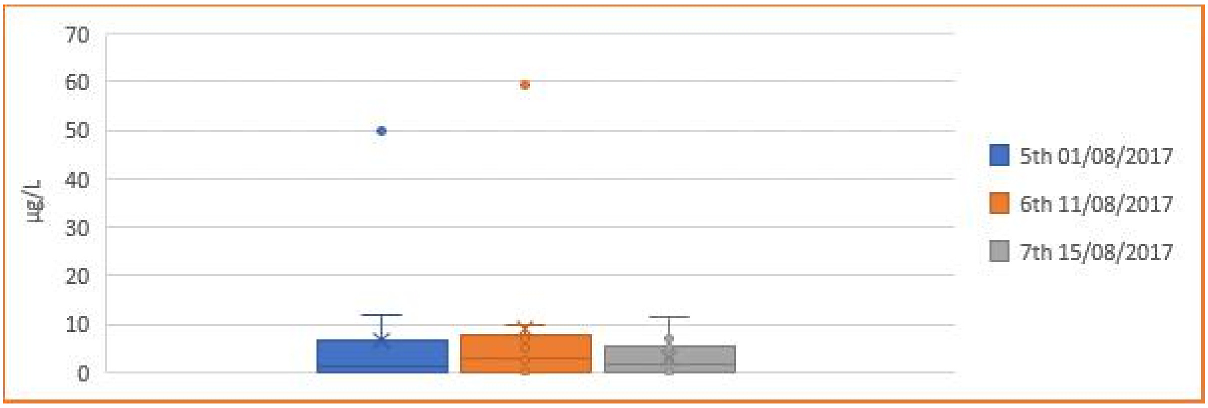


Figure 4- 27: On-site VSS results

4.5 Comparison with BMP database land use data and onsite data

To identify the right BMP datasets to compare with the data obtained on-site the Event Mean Concentration (EMC) had to be calculated for each element for each storm event. EMC was calculated by using equation 3-1 and this is generally used to calculate the average reduction in pollutant concentration for any given storm (Ereckson, et al., 2010).

The land uses were identified in Chapter 3: Methodology, based on the same characteristics of the study site. These were Parking lots (Park and Ride), office buildings and university buildings. Within this section the on-site data was compared with the identified land uses, using the same sites for each element, if available. All the graphs can be found in Appendix C, where the raw data extracted from the BMP database can be found in Appendix A3.

The total EMC graphs for As, Cu and Zn can be seen in Figures 4-28, 4-29 and 4-30 respectively.

The As on-site concentrations showed lower total concentrations than the sites in the BMP database. Cu correlated well with the databases data, and Zn concentrations were much higher onsite than found in the database. This indicated that (a) the land uses identified for comparing the onsite data with the BMP database would not be sufficient enough to be used for comparing the same land uses or (b) the variation between pollution at different locations were too great to develop a concentration standard per land use.

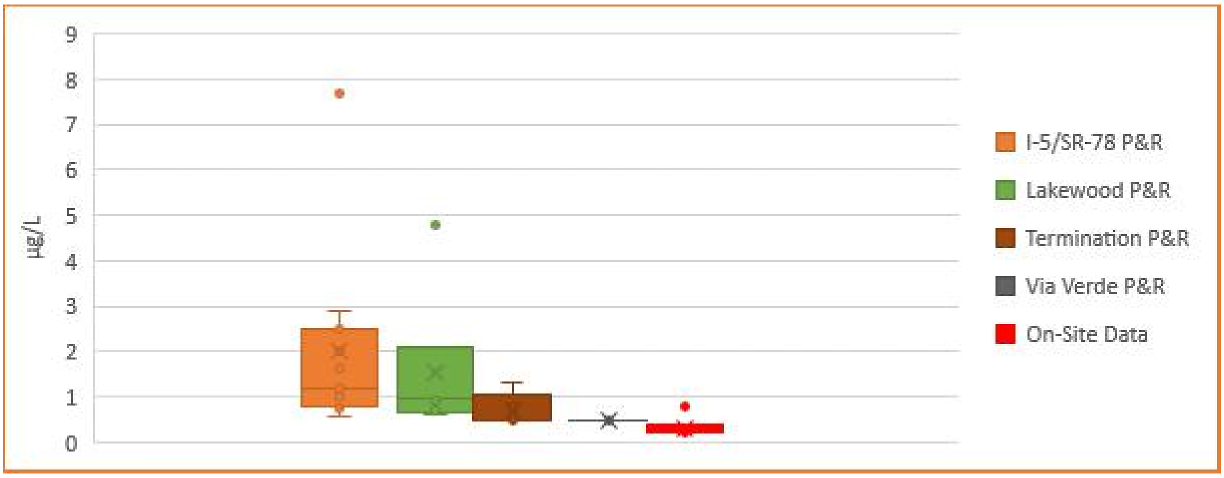


Figure 4- 28: Initial total EMC As compared with different land use sites in the BMP database

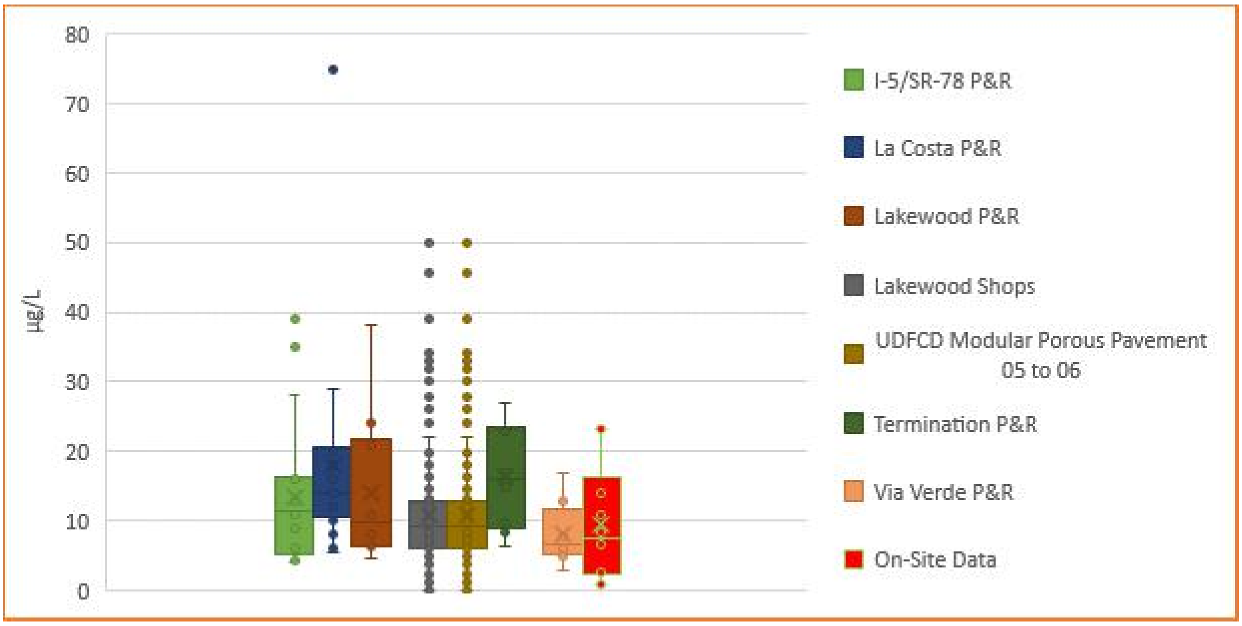


Figure 4- 29: Initial total EMC Cu compared with different land use sites in the BMP database

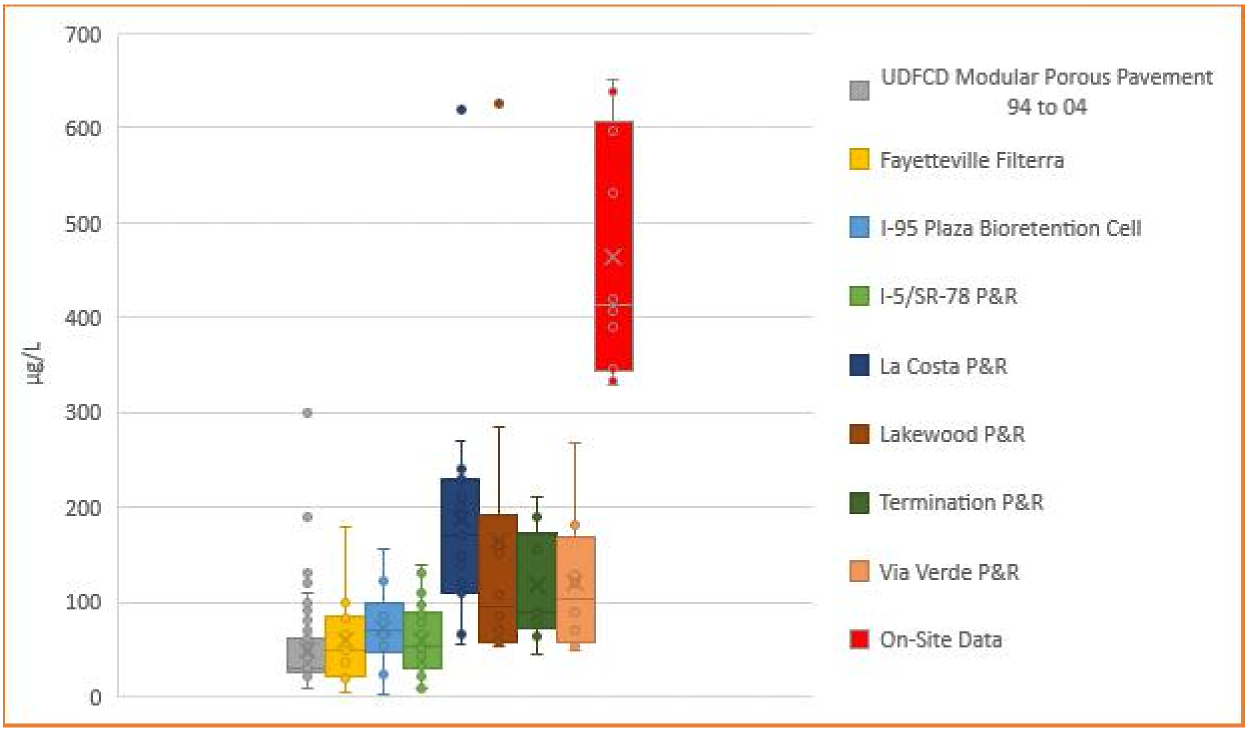


Figure 4- 30: Initial total EMC Zn compared with different land use sites in the BMP database

Due to the As and Zn concentrations being very dissimilar to those found in chosen land use types from the BMP database, different land uses were identified to be compared with the on-site data. This was done by using the same steps as explained in the Methodolody chapter, but filtering the

"WQ Analysis" tab and selecting values smaller than the highest EMC As found on site (0.672µg/L), and values larger than the lowest concentration found on site (0.2µg/L).

There were up to 19 different sites identified that had values within the range discussed above. Amongst all the different sites, five different land uses were identified. Medium Density Residential, Roads/Highways, Office Commercial, Low Density Commercial and Maintenance Station. Figure 4-31 below shows the different land uses from the BMP database compared with the on site data for total As EMC. The graph shows that for the Meduim Density Residential, Low Density Commercial and Office Commercial only one of the concentration values found in the database falls within the spectrum of the on-site data.

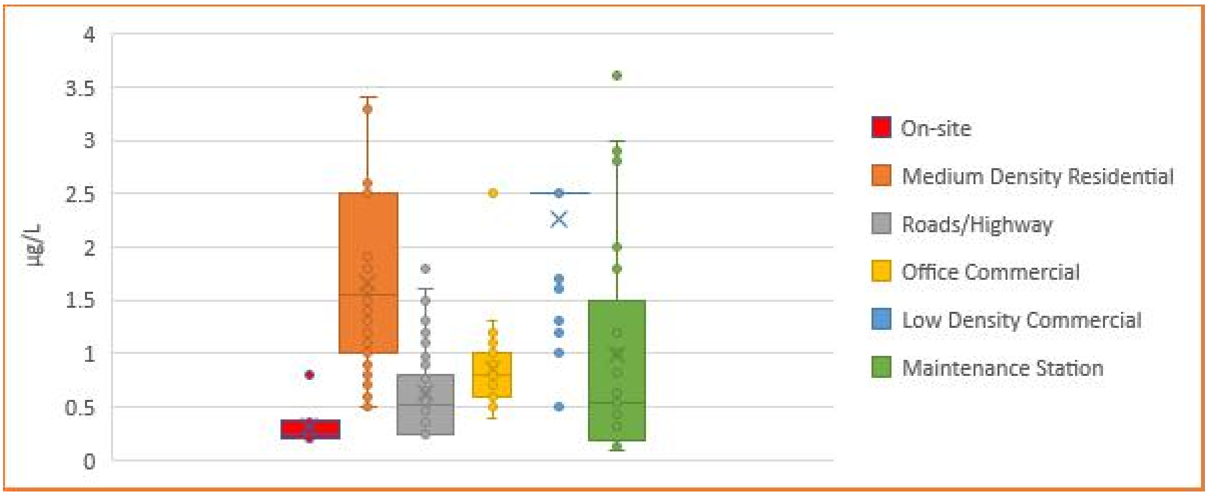


Figure 4- 31: Total EMC As - different land uses

Figure 4-32 show the different land uses identified for Dissolved As, which also shows that Roads/Highways were in range of the Dissolved EMC data.

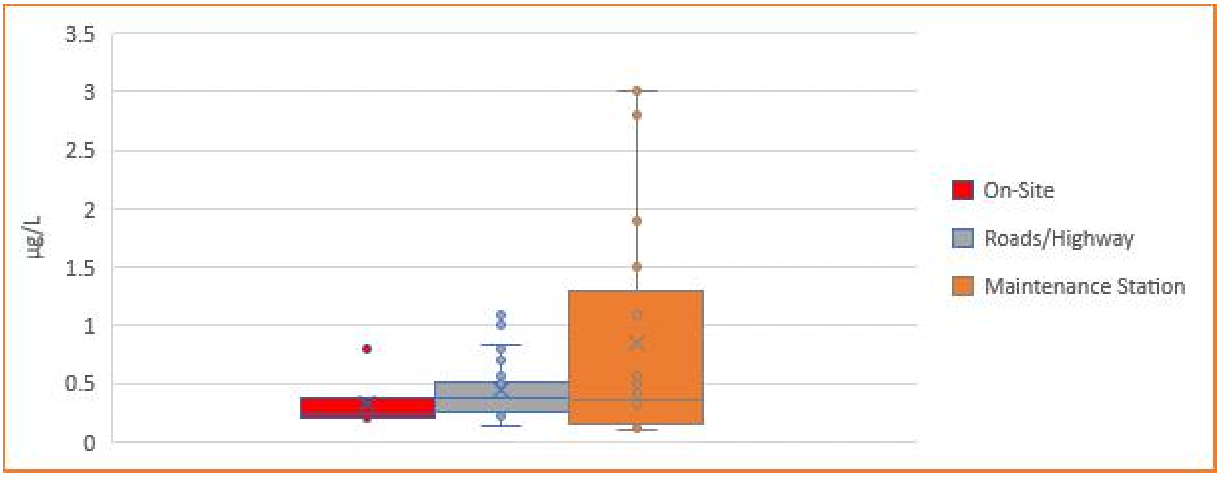


Figure 4- 32: EMC Dissolved As - different land uses

From the tests it was found that the dissolved concentrations are the same land use types identified with the total concentrations. Figure 4-33 shows that there are different landuses that falls within the range of the onsite data for dissolved Cd. The maintenance Station concentrations were much smaller than with the other landuses, where Low Density Commercial were in range, with a few outliers which was much more than the on-site data up to 5µg/L, where the highest concentration for Total Cd was 0.723 µg/L. Dissolved Cd showed that Low Density Residential and Roads/Highways had in-range concentrations, this figure can be found in Appendix C.

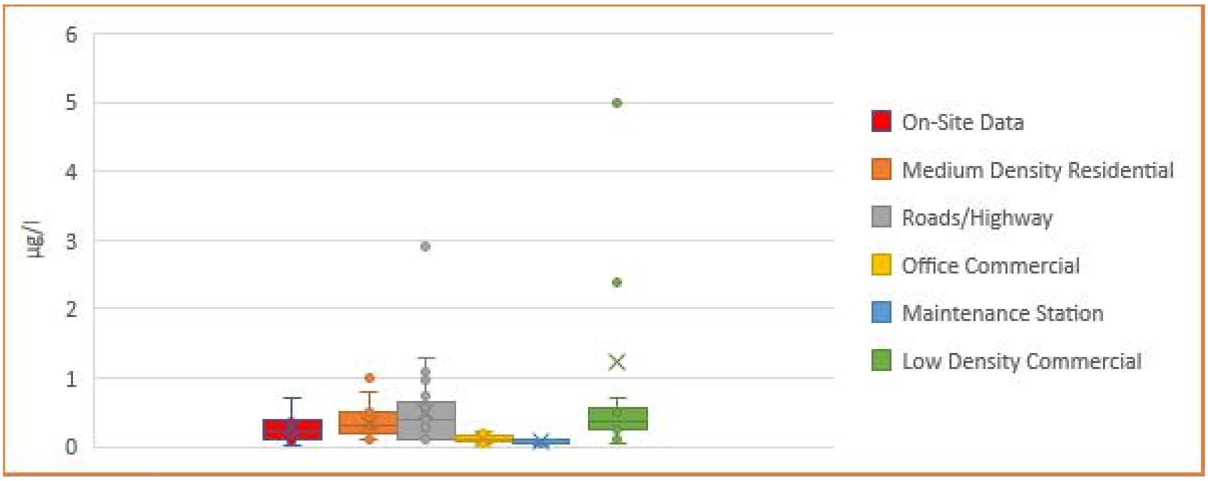


Figure 4- 33: Total Cd BMP database – different land uses

Total Cu indicated that all the land use types in Figure 4.34 was within range of the on-site data. With dissolved Cu the Maintenance Station and Office commercial was not as in-range as with the other land uses, this figure can be found in Appendix C.

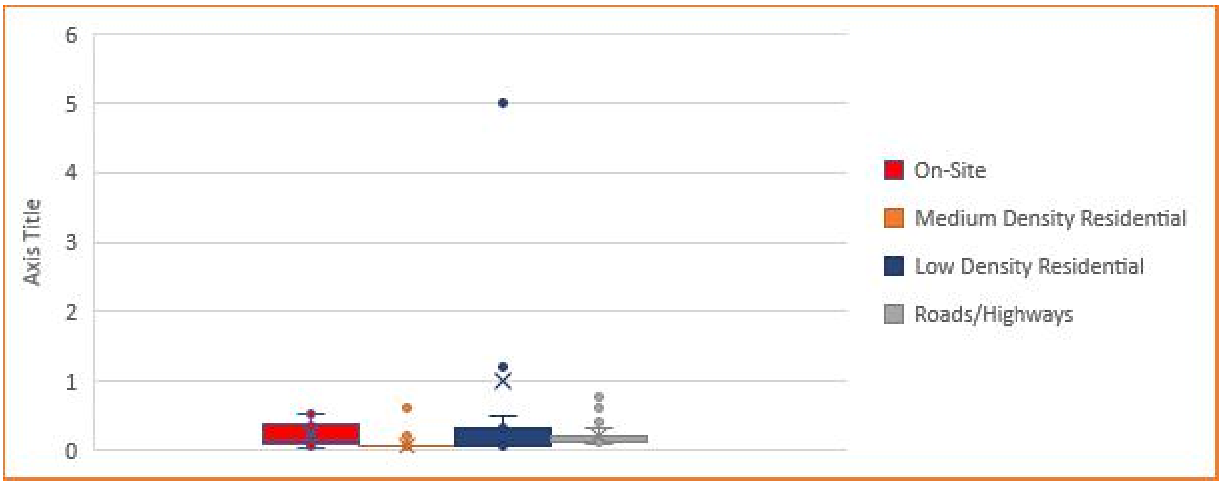


Figure 4- 34: EMC total Cu - different land uses

Zn had a much larger range than the other constituents, 327.56 – 773.76µg/L, providing over 80 different sites that provide concentration values as found on-site. It was decided to only use the sites used with the other elements. Where it was found that the Zn concentrations found on-site was still more than the database provides, see Figure 4-35. Zn was filtered within the spectrum of the 25th and 75th percentile on the BMP database, where it was found that the best correlation for Zn was Medium Density Residential land use.

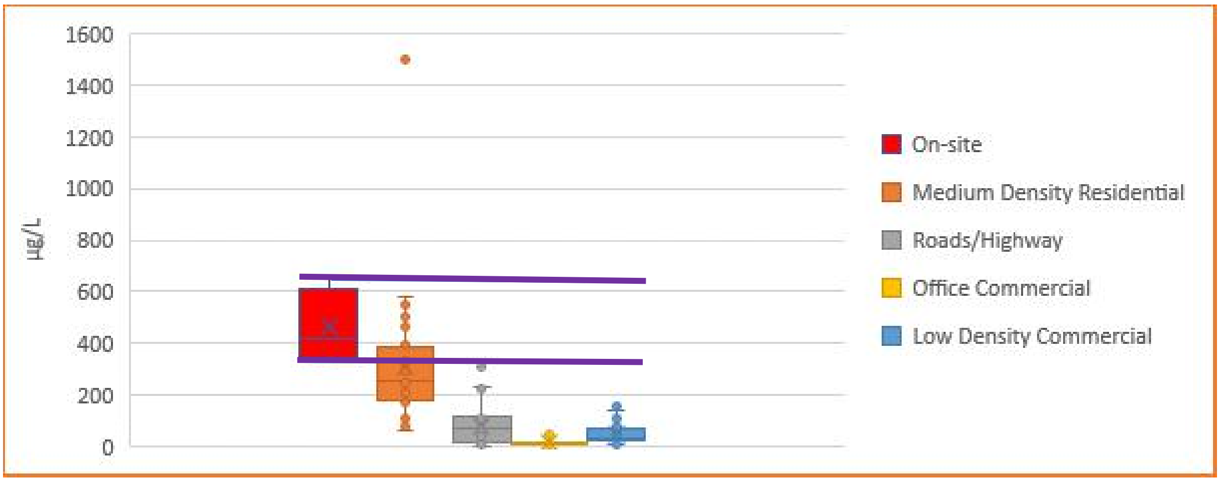


Figure 4- 35: EMC total Zn - different land uses

From the graphs this is not conclusive what the exclusive range is the best land uses that can be compared with the onsite data is Roads and Highways for all the different constituents. But, for Zn the better land use to be compared with the onsite data is heavy industrial land use from the BMP database.

4.6 Statistical evaluation

Different correlations were calculated using each storm event separately, by first comparing As with Cd, which gave a correlation of 0.7 between the two datasets for the same storm event. Table 4-2 shows the correlation between the different metal constituents. The table shows that the best correlation was found between the filtered Cu and Zn concentrations with a correlation (r^2) of 0.985, during the fifth storm event. Figure 4-36 shows the correlation between Cu and Zn throughout the storm event from zero hours to nine and a half hours.

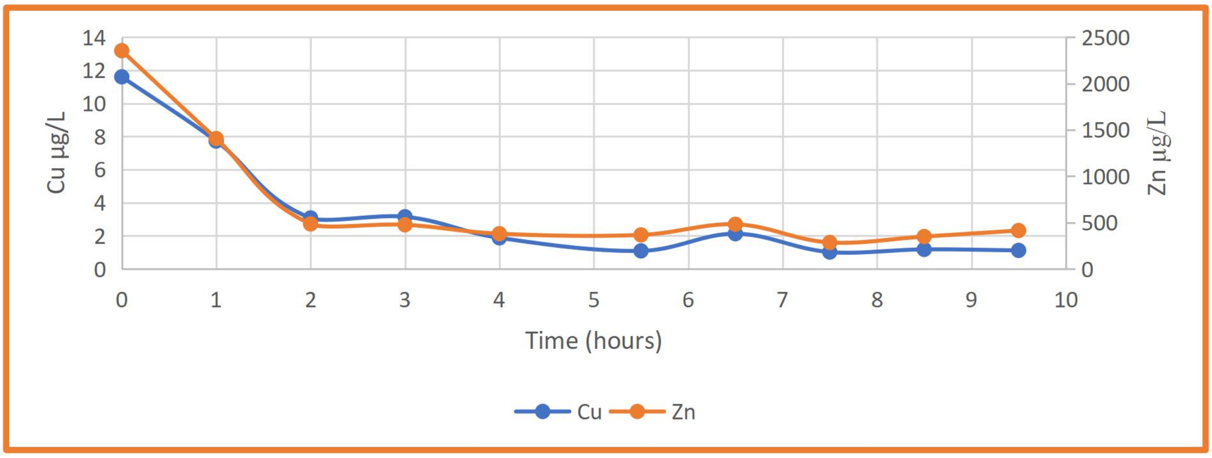


Figure 4- 36: Correlation between Cu and Zn over one storm event

The overall worst correlation was between the unfiltered Cu and Pb, during the second storm event, giving a correlation of -0.00156, as seen in Table 4-2. Figure 4-37 provides a graphic illustration of the poor correlation between the concentrations of Cu and Pb.

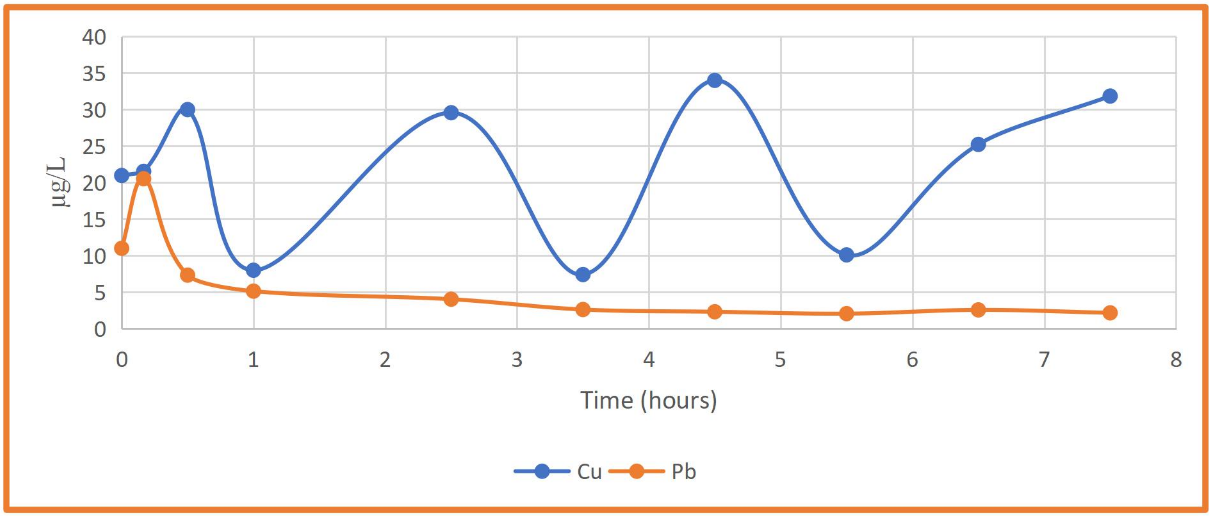


Figure 4- 37: Correlation between Cu and Pb over one storm event

The concentrations that showed the best correlation throughout the sampling period was found to be between As and Zn. The average correlation between As and Zn throughout the sampling period was found to be 0.72. The better the correlations between different parameters within the study the easier it would be to create removal efficiency model for future stormwater quality control systems with the same characteristics as the site.

Table 4-2 provides the correlation, showed as R, between the elements throughout the sampling period. The sixth and seventh storm events showed the worst correlation for all the samples. Here no correlation was found between As and the other elements. This was due to the concentrations of the total and dissolved being the same for all the samples. The fifth storm event showed the best correlation for all the filtered samples, with all the correlations was above 0.83. Seven of the correlation coefficients for the fifth storm event were found to be above 0.9 and the other three were between 0.83 and 0.88. During the fifth storm event a low intensity storm was recorded where the intensity reduced at the end of the storm event. This indicates that with low intensity storms there were better correlation between the different elements. The lowest overall correlation was recorded during the tenth storm event, which had the longest rainfall period for all storm events. The sixth storm event provided the highest intensity storm, and here there was a low correlation between the elements. Therefore, this shows that metals concentrations were not well correlated overall, except of one storm, indicating that metals concentrations cannot be used as proxies for one another in stormwater runoff water quality modelling.

The boxes in Table 4-2 highlighted orange shows the best correlations between samples (0.9 – 0.99), and the red boxes show the worst correlations (-0.09 - 0.09).

	Storm Events																			
	1st		2nd		3rd		4th		5th		6th		7th		8th		9th		10th	
	F	UF	F	UF	F	UF	F	UF	F	UF	F	UF	F	UF	F	UF	F	UF	F	UF
As & Cd	0.70	-0.18	0.30	0.16	0.31	0.54	0.12	0.96	0.83	0.92	-	-	-	-	0.51	0.55	0.76	0.57	-0.18	-0.10
As & Cu	0.43	0.24	0.77	0.04	0.14	0.07	-0.06	0.43	0.98	0.52	-	-	-	-	0.73	0.55	0.64	0.62	0.95	0.98
As & Pb	0.49	0.38	0.98	0.93	0.44	0.35	0.05	0.37	0.92	0.94	-	-	-	-	0.46	0.72	-0.05	0.37	-0.02	0.20
As & Zn	0.66	0.65	0.93	0.87	0.75	0.81	0.88	0.76	0.96	0.97	-	-	-	-	0.39	0.23	0.69	0.42	0.69	0.80
Cd & Cu	0.40	-0.31	0.28	0.19	0.09	0.48	0.26	0.42	0.88	0.45	-0.30	0.53	0.10	0.26	0.26	0.43	0.65	0.95	-0.17	0.00
Cd & Pb	0.84	0.74	0.21	0.11	0.04	0.35	-0.21	0.14	0.85	0.89	-0.20	-0.43	-0.08	-0.46	0.48	0.41	0.25	0.89	0.13	0.13
Cd & Zn	0.49	-0.08	0.04	0.38	0.32	0.61	0.14	0.77	0.90	0.90	0.23	0.60	-0.54	-0.65	0.65	0.71	0.46	-0.29	-0.05	0.00
Cu & Pb	0.20	-0.02	0.73	0.00	0.67	0.18	0.24	0.20	0.95	0.58	-0.05	-0.16	-0.06	-0.15	0.43	0.56	0.22	0.79	0.03	0.30
Cu & Zn	0.37	0.39	0.69	0.06	-0.35	0.35	-0.26	0.54	0.99	0.53	0.32	0.00	0.06	-0.09	0.11	0.10	0.11	-0.14	0.68	0.87
Pb & Zn	0.35	0.29	0.91	0.68	0.22	0.53	-0.07	0.09	0.98	0.98	-0.63	-0.68	0.39	0.55	-0.10	-0.14	-0.59	-0.64	0.61	0.60
UF = Unfiltered; F = Filtered; - no correlation data; R^2 = correlation coefficient																				

Table 4- 2: Correlation coefficient (R^2) between different metals during storm events

Table 4-3 shows the percentage of each element concentration compared to the total concentration of all elements, showing the average results of the Dissolved, Total and Particulate metals. Zn had up to 97.65% of the total dissolved concentration found in all the samples, and 96.76% of the Total concentrations throughout the sampling period. The lowest concentrations found in the samples were As and Cd. These were found to be 0.06%, 0.07% and 0.19% for Dissolved, Total and Particulate concentrations respectively. For Cd the percentage was 0.05%, 0.05% and 0.36% for Dissolved, Total and Particulate from all the different metals tested throughout the sampling period.

Table 4- 3: All average heavy metal results compared with each other

Storm events		1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	Average
% Dissolved	As	0.09%	0.06%	0.04%	0.04%	0.05%	0.06%	0.05%	0.06%	0.05%	0.05%	**0.06%**
	Cd	0.02%	0.07%	0.12%	0.09%	0.05%	0.04%	0.04%	0.01%	0.02%	0.03%	**0.05%**
	Cu	1.46%	1.57%	3.20%	3.84%	0.48%	0.21%	0.40%	0.72%	0.90%	0.69%	**1.35%**
	Pb	0.94%	0.28%	0.34%	0.32%	0.32%	0.52%	0.10%	0.63%	1.05%	4.46%	**0.90%**
	Zn	97.50%	98.03%	96.30%	95.71%	99.10%	99.16%	99.41%	98.58%	97.98%	94.76%	**97.65%**
%Total	As	0.08%	0.13%	0.06%	0.05%	0.05%	0.06%	0.05%	0.05%	0.05%	0.05%	**0.07%**
	Cd	0.02%	0.06%	0.11%	0.07%	0.02%	0.07%	0.08%	0.01%	0.05%	0.03%	**0.05%**
	Cu	1.26%	3.39%	4.55%	3.42%	1.67%	0.29%	0.43%	0.64%	0.93%	0.59%	**1.72%**
	Pb	0.42%	0.93%	0.95%	0.97%	1.06%	0.49%	0.09%	0.98%	1.43%	6.74%	**1.41%**
	Zn	98.22%	95.50%	94.33%	95.49%	97.20%	99.09%	99.35%	98.32%	97.54%	92.59%	**96.76%**
%Particulate	As	0.03%	0.55%	0.37%	0.62%	0.16%	0.00%	0.00%	0.05%	0.07%	0.08%	**0.19%**
	Cd	0.07%	0.07%	0.32%	0.17%	0.02%	0.31%	1.89%	0.01%	0.75%	0.01%	**0.36%**
	Cu	0.36%	13.20%	80.16%	39.54%	47.74%	1.14%	4.26%	0.14%	6.23%	0.67%	**19.34%**
	Pb	0.00%	4.39%	19.15%	59.67%	29.44%	0.23%	0.17%	13.36%	8.80%	32.64%	**16.79%**
	Zn	99.55%	81.78%	0.00%	0.00%	22.65%	98.32%	93.68%	86.43%	84.15%	66.59%	**63.32%**

Correlation between the onsite data and the BMP database data was calculated in Excel (Excel, 2013). Each case provided a different land use. Medium Density Residential, Roads and Highways, and Office Commercial. Table 4-4 provides the correlation results of the Total onsite EMC values over the sampling period with Total data EMC from the BMP database. The analysis showed that the most similar sites to the investigated Parking Lot in terms of As concentrations was Office Commercial with a value of 0.96 or Roads and Highways with a value of 0.95. Cd showed the best correlation value of 0.98 under Roads and Highways, and between 0.74 and 0.95 for Office Commercial. The best correlation value for Cu was 0.98 under Roads and highways. For Pb it was 0.98 for roads and highways but also for the lowest correlation value, 0.02, was recorded under roads and highways. Zn showed the best correlation value of 0.97 under Medium Residential, and 0.91 under one of the Roads and Highways cases. As stated above, the Zn correlated best with heavy industrial sites on the BMP database, although the correlation values between the different cases and the onsite case were higher than expected. Zn had a wide variation of possible concentrations which make it harder to identify the best land use that can be compared with the element.

It is found that the site with the best correlation values for most elements was Case 3, which is office commercial. The best correlations is highlighted in orange.

Case num.	BMP database comparable areas	Land use	As	Cd	Cu	Pb	Zn
Case 1	21st and Iris Rain Garden inlet	Medium Density Residential	0.85	0.97	0.75	0.62	0.97
Case 2	Cottonwood RVTS	Roads/Highway	0.89	0.82	0.82	0.98	0.50
Case 3	Elm Drive	Office Commercial	0.92	0.97	0.92	0.93	0.48
Case 4	Grant Ranch	Low Density Commercial	0.57	0.85	0.95	0.97	0.73
Case 5	IX-2	Office Commercial	0.80	0.74	0.81	0.73	0.64
Case 6	IX-3	Office Commercial	0.67	0.71	0.93	0.36	0.48
Case 7	IX-4	Office Commercial	0.66	0.91	0.84	0.87	0.73
Case 8	IX-5	Office Commercial	0.96	0.94	0.84	0.63	0.56
Case 9	IX-7	Office Commercial	0.63	0.95	0.92	0.82	0.63
Case 10	Moreno A RVTS	Roads/Highway	0.89	0.98	0.84	0.42	0.81
Case 11	Moreno B RVTS	Roads/Highway	0.35	0.72	0.84	0.61	0.91
Case 12	Mount Shasha Maintenance Station Sand Filter Influent	Maintenance Station	0.59	0.74	0.88	0.48	0.77
Case 13	Mountain Gate Sand Filter Influent	Roads/Highway	0.95	0.94	0.84	0.87	0.86
Case 14	Murrieta RVTS	Roads/Highway	0.83	0.93	0.98	0.51	0.84
Case 15	Redding RVTS	Roads/Highway	0.54	0.94	0.91	0.77	0.59
Case 16	Sacramento RVTS	Roads/Highway	0.60	0.87	0.97	0.35	0.90
Case 17	San Onofre RVTS	Roads/Highway	0.88	0.87	0.94	0.02	0.86
Case 18	San Rafael RVTS	Roads/Highway	0.83	0.96	0.86	0.65	0.69
Case 19	Yorba Linda RVST	Roads/Highway	0.88	0.90	0.98	0.35	0.88

Table 4- 4: Total metals correlation (R) between different elements and BMP database

Table 4-5 provides the Dissolved metals correlation values for onsite EMC and BMP database. The same cases were used as with the total EMC values. Most of the Office commercial cases did not provide values for dissolved metals. Although, there were values for dissolved Zn, which showed better correlation than the other land uses, ranging between 0.85 and 0.94, where the other land uses ranged between 0.76 and 0.93.

Dissolved As best correlation was 0.94, for Case 13: Mountain gate sand filter influent, which is roads and highways. The best adjusted correlation for Cd was 0.98 also under roads and highways, which was almost near perfect correlation between the database and the concentration recorded during the sampling period. The highest correlation value for Cu was 0.94 for roads and highways.

The site with the best correlation was total Cd EMC compared with Case 17: San Onofre RVTS Roads and Highways, which provided a correlation of 0.98. The site with the best correlation for all dissolved element EMC were Case 14: Murrieta RVTS Roads and Highways for Cu at 0.97. The overall best correlations is highlighted in orange.

Table 4- 5: Dissolved metals correlation (R) between different elements and BMP database

Case num.	BMP database comparable areas	Land use	As	Cu	Cd	Pb	Zn
Case 1	21st and Iris Rain Garden inlet	Medium Density Residential	0.69	0.69	0.90	0.52	
Case 2	Cottonwood RVTS	Roads/Highway			0.86	0.61	
Case 4	Grant Ranch	Low Density Commercial			0.83	0.16	
Case 7	IX-4	Office Commercial					0.91
Case 8	IX-5	Office Commercial					0.94
Case 9	IX-7	Office Commercial					0.85
Case 10	Moreno A RVTS	Roads/Highway	0.77	0.77	0.95	0.75	0.93
Case 11	Moreno B RVTS	Roads/Highway	0.50	0.50	0.01	0.59	0.91
Case 12	Mount Shasha Maintenance Station Sand Filter Influent	Maintenance Station	0.69	0.69	0.88	0.00	0.91
Case 13	Mountain Gate Sand Filter Influent	Roads/Highway	0.94	0.94	0.82	0.00	0.76
Case 14	Murrieta RVTS	Roads/Highway	0.92	0.92	0.92	0.72	0.95
Case 15	Redding RVTS	Roads/Highway	0.90	0.90	0.88	0.60	0.82
Case 16	Sacramento RVTS	Roads/Highway	0.66	0.66	0.92	0.63	0.90
Case 17	San Onofre RVTS	Roads/Highway	0.90	0.90	0.98	0.02	0.83
Case 18	San Rafael RVTS	Roads/Highway	0.80	0.80	0.95	0.63	0.86
Case 19	Yorba Linda RVST	Roads/Highway	0.63	0.63	0.85	0.40	0.82

Therefore, the best correlation between the BMP database and the study site was found to be Roads and Highways. For Zn it was found that Heavy Industrial land use correlates better than the Roads and Highways. Also, the highest constituent concentration was found to be Zn, which were more than 95% of the total mass of all the samples throughout the sampling period.

4.7 Discussion

- Traffic on site was mainly over capacity during the semester or when it was holidays the parking lot was only between 10 – 20% of the capacity used.
- The storm events were not constant, providing a vast range of variables that needed to be considered such as: dry days, low rainfall year, varying usage of parking lot, and rainfall intensities.
- The first samples were taken 10 May 2017 and the last samples were taken 20 November 2017. The last rainfall event provided the longest storm event throughout the sampling period, 45 hours, with a gauge reading of 23mm. The sixth storm event provided the highest rainfall reading of 49mm. Due to dangerous conditions samples were only taken for 7.5 hours at 23mm gauge reading.
- Stormwater quality parameters tested for was As, Cd, Cu, Pb, Zn and TSS, VSS and ISS.
- It was expected that all concentration would be higher during higher intensity storms. It was observed that the lower the intensity of the storm the lower the concentration of Cd, and the higher the intensity of the storm the higher the concentration. With Cu the opposite was observed, the lower the storm intensity the higher the concentration, and the higher the storm intensity the lower the concentration. The highest dissolved Cu was observed after a 20-day dry period with a very low intensity storm.
- As, Cd, Cu, and Zn showed lower concentrations than the SANS 241 health limit for drinking water. On average, the concentrations for As, Cd, Cu and Zn were 93.3%, 75%, 99.05% and 80% respectively less than the SANS241 health limit. Pb was found to be too high for drinking purposes, in one case the Pb is 32 times above the drinking standards. The probable cause of the high Pb concentration can be due to an old car leaking Pb containing petrol or wash off from an old car. More test needs to be conducted to find the source of this high concentrations, with a continuous study of what is happening on the parking when it is not raining. Precautionary measures would need to be implemented to reduce the Pb concentration significantly. This was further discussed within the preliminary design in the next chapter.

- If there is a consistent rainfall event, meaning the same rainfall intensity occurs throughout the storm, and there are no durations of rain stopping and starting again, the first flush phenomenon is plausible. Upon general observation it was found that the first flush phenomenon is not true in the storm events recorded throughout the sampling period, due to lack of consistent rainfall periods.

- The different constituent concentrations with the highest and lowest values recorded over the sampling period can be found in Table 4-6.

Table 4- 6: Concentration ranges of different constituents tested

Different Constituents Tested	Unfiltered (Total)		Filtered (Dissolved)		Particulate	Mass
	Highest	**Lowest**	**Highest**	**Lowest**	**Highest**	**Highest**
As	2.14 µg/L (2nd sample on 2nd sampling day)	0.1 µg/L (observed on the 1st, 3rd, 4th sampling days)	1.08 µg/L (1st sample on the 5th sampling day)	0.1 µg/L (observed on the 1st, 2nd , 3rd, 4th and 5th sampling days)	1.5 µg/L (2nd sample on the 2nd sampling day)	54.8 µg
Cd	2.057 µg/L (6th sample on 10th sampling day)	0.01 µg/L (observed on the 1st, 8th and 9th sampling days)	1.14 µg/L (1st sample of the 4th sampling day)	0.02 µg/L (observed on the 1st and 9th sampling days)	1.19 µg/L (6th sample on 10th sampling day)	160.7 µg
Cu	41.36 µg/L (10th sample on 3rd sampling day)	0.22 µg/L (6th sample on 6th sampling day)	51.58 µg/L (6th sample on 3rd sampling day)	0.13 µg/L (6th sample on 6th sampling day)	26.256 µg/L (4th sample on 3rd sampling day)	3.1 mg
Pb	319 µg/L (8th sample on 10th sampling day)	0.11 µg/L (2nd sample on 7th sampling day)	210.79µg/L (8th sample on 10th sampling day)	0.18 µg/L (4th and 5th sample on 7th sampling day	107.84 µg/L (6th sample on 8th sampling day)	35.56 mg
Zn	2348 µg/L (1st sample on 5th sampling day)	128 µg/L (5th sample on 6th sampling day)	2354 µg/L (1st sample on 5th sampling day)	129.6 µg/L (5th sample on 6th sampling day)	312 µg/L (10th sample on 6th sampling day)	162.56 mg

- Land uses identified in the methodology chapter were not enough for comparing the on-site concentrations and BMP Database data. Therefore, other land uses were identified which best suited the different constituents. The best correlation land use types were found to be roads and highways, and office commercial. Zn concentrations were much higher than that of office commercial and best correlated with roads and highways, and heavy industrial land use. This indicates that the establishment of typical runoff metals concentrations for specific land uses may be possible. Future research towards establishing a guideline containing typical concentrations is therefore warranted.

- The best metal cross correlations were found during the fifth storm event between Total Cu and Zn, with a correlation coefficient of 0.985. The worst correlation between metals were during the second storm event between Dissolved Cu and Pb at -0.00156. This indicates that different metals concentrations cannot be used as proxies for one another during stormwater quality treatment modelling.

Chapter 5 Stormwater Harvesting Design

5.1 Introduction

Due to the intense drought experienced in Cape Town, new and innovative should be developed for managing water more effectively. This preliminary design can be used as a possible solution to alleviate potable water shortages on a small scale. It is noted that each design for stormwater management should be site specific; therefore, this design is only for the site studied. The design procedure may however be a basis for other sites, but the specific ground and climate conditions for these sites should be considered.

5.2 Technical Review

Historical measures for providing potable water to the public have been dams, rivers, wells, boreholes and streams. With climate change, and more countries looking at alternative measures to obtain water sources, new innovative ideas need to be examined and implemented. Dams pose many problems for using water sustainably, as large volumes of water are lost due to leaks in the system, evaporation, and infiltration. Dam capacity also limited to available and appropriate sites.

Due to the drought the CoCT started looking at alternative measures providing potable water, such as more boreholes and wells, desalination and treated effluent reuse. Desalination is not deemed a sustainable and economical solution, primarily due to its high energy demand, as well as the detrimental effect it has on marine ecosystem due to the concentration of chemical discharges (Lattemann & Hopner, 2008). The city has reduced its water consumption by roughly 50%, with citizens implementing their own measures of sustaining water. Almost half of the city kept to the daily limit of 50l/person/day, by doing this the citizens used measures such as reusing greywater for flushing, and installing rainwater harvesting tanks at their homes. CoCT achieved this within 3years, where it took Australia almost 12years to reduce the water consumption by half. (Villiers, 2018)

It was found that stormwater harvesting is not widely used in South Africa. This design is an example of how stormwater harvesting systems can be approached to alleviate water problems for future generations. The design is based on commonly used civil engineering calculations and techniques. The bio-retention design, however, is not widely used in South Africa, where there are no specific guidelines on designing, but was based on the principles set out in Chapter 2.

Using the results from Chapter 4, it was found that Pb is higher than SANS 241 water drinking quality standards. Therefore, the plants chosen for the biofiltration garden was based on reducing Pb concentration.

5.3 Design requirements

The design elements entail slabs, beams, columns, retaining walls, drainage alterations and finally a bio-retention garden. The site that was identified for the design is shown in Figure 5.1 with a location adjacent to the research project sampling point. This is next to the water laboratory of the engineering faculty. The size of the proposed reservoir is 7m x 40 m with a depth of 5m providing reservoir capacity of 1 400 m^3. The area of the bio-retention garden is approximately 423 m^2 and is shown in Figure 5-1. The harvested water is intended for used in the faculty for toilet flushing, and garden irrigation. If found to be consistently pure enough for drinking water, it could also be used as potable water in kitchens and handwashing. It is noted that various other pathogens need to be tested for potable use.

The constituent concentration showed that Pb would be a problem if the water is to be used for drinking purposes. Options available for alleviating different metal concentrations would include the construction of a bio-retention garden, which can alleviate not only the Pb concentration but also other impurities.

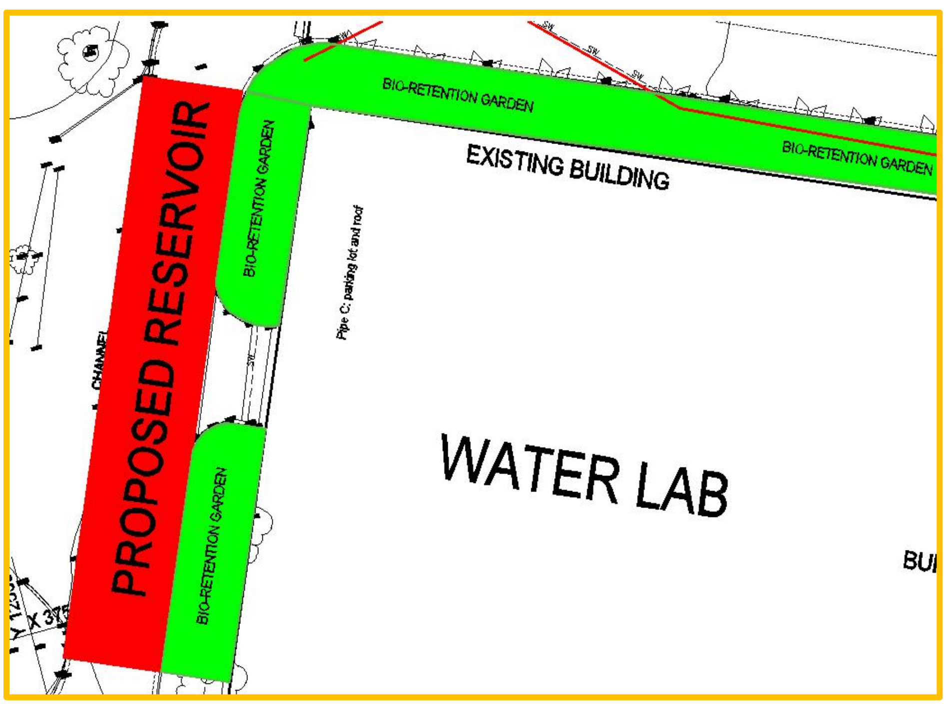


Figure 5- 1: Proposed reservoir and bio-retention garden site

5.3.1 Hydraulic study

The north side of the engineering faculty uses up to 160 m^3 of water during the semester per week (information provided by the engineering faculty staff, who conducted their own daily readings in Jan/Feb 2018). Toilets use most of the water in any given building, therefore the preliminary design is based on providing flushing water for the faculty throughout the year. This will reduce the need for in-depth testing, monitoring and disinfection of the stormwater.

If 80% of the stormwater is used for flushing, up to 512m^3 is needed per month to ensure that there is enough water. Table 5-1 shows how the water usage for each month was broken down. Assuming that during the summer holidays, which runs from December to January, there is only one week of the total demand needed, therefore, only 128m^3 for the month of December and January. During the months with short holidays, three weeks is allocated, therefore the month of April (many public holidays and Easter break) only uses 384m^3. Also, during the winter break, students come back earlier or must stay longer for second round of exams. These values were used in the hydrological study for the demand of each month.

Table 5- 1: North side of faculty possible flushing demands

Month	Assumed monthly usage over a year period	Demand (80%)	Demand (100%)
January	1 Week (Summer holidays)	128 m^3	160 m^3
February	4 Weeks	512 m^3	640 m^3
March	4 Week	512 m^3	640 m^3
April	3 Weeks (one-week holiday and plenty with many public holidays)	384 m^3	480 m^3
May	4 Weeks	512 m^3	640 m^3
June	4 Weeks	512 m^3	640 m^3
July	2 Weeks (University Winter Holiday)	256 m^3	320 m^3
August	4 Weeks	512 m^3	640 m^3
September	3.5 Weeks (one-week holiday, but many students stay on campus)	448 m^3	560 m^3
October	4 Weeks	512 m^3	640 m^3
November	3 Weeks (Holiday starts in the middle of the month)	384 m^3	480 m^3

December	1 Week (Summer Holidays)	128 m^3	160 m^3

The historical rainfall used for the hydrological study can be seen in Table 5-2.

Table 5- 2: Historical rainfall Stellenbosch, Western Cape, South Africa (mm) (La Colline Observatory, Stellenbosch Weather Station, 2018)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total (mm)
2017	13.5	0	7.7	33.8	10.5	142.9	61.7	69.2	26.4	36.4	46.7	20	468.8
2016	0	0	56.7	53.9	18.1	104.3	104.7	84.9	56	21.9	1.4	8.9	510.8
2015	18	6	2.2	8.8	32.4	124.4	105.3	43.1	22	6.4	0	16.5	385.1
2014	45.8	2	47.9	28.6	71.8	209.8	126.9	117.9	30.9	4.7	42.8	6.3	735.4
2013	15.7	66.5	17.1	57.9	72.7	156	96.4	229	103.7	41.1	135.1	2.7	993.9
2012	1.1	5.2	32.1	44.6	87	140.7	148.2	169.6	121.8	98.7	8.6	0	857.6
2011	6.3	3	6.9	50.6	74.7	113.4	43.6	94	41.5	27.6	44.4	24.8	530.8
2010	0.6	21.1	5.8	13.1	142.9	132.3	62	63	32	64.2	36.7	11.2	584.9
2009	7.9	10.7	5.4	43	98.9	185.7	106.4	138	80.5	50.4	84.7	0.3	811.9
2008	19.6	37.4	24.3	20.8	80.7	101.3	240.4	117.6	129	15.9	51.4	8.4	846.8
2007	3.6	33.2	39.7	93.5	79.7	127.6	156.1	140.4	31.3	68.1	41.7	19.9	834.8
2006	0	21.9	7.8	49.8	155.5	87.8	125.6	101.9	34.6	39.2	47.3	20	691.4
2005	61.5	0.2	19.7	83.4	128.8	155.1	84.4	117.3	48.2	32.8	29.7	0	761.1
2004								37	50.5	140.6	9	5.1	242.2
Reference: (Stellenbosch University, n.d.)													

The total rainfall for each year is shown in figure 5-1, where it provides a clear indication of downward trend in rainfall over the last 10 years. This supports the fact that fast and efficient measures need to be put in place for future sustainable usage of water.

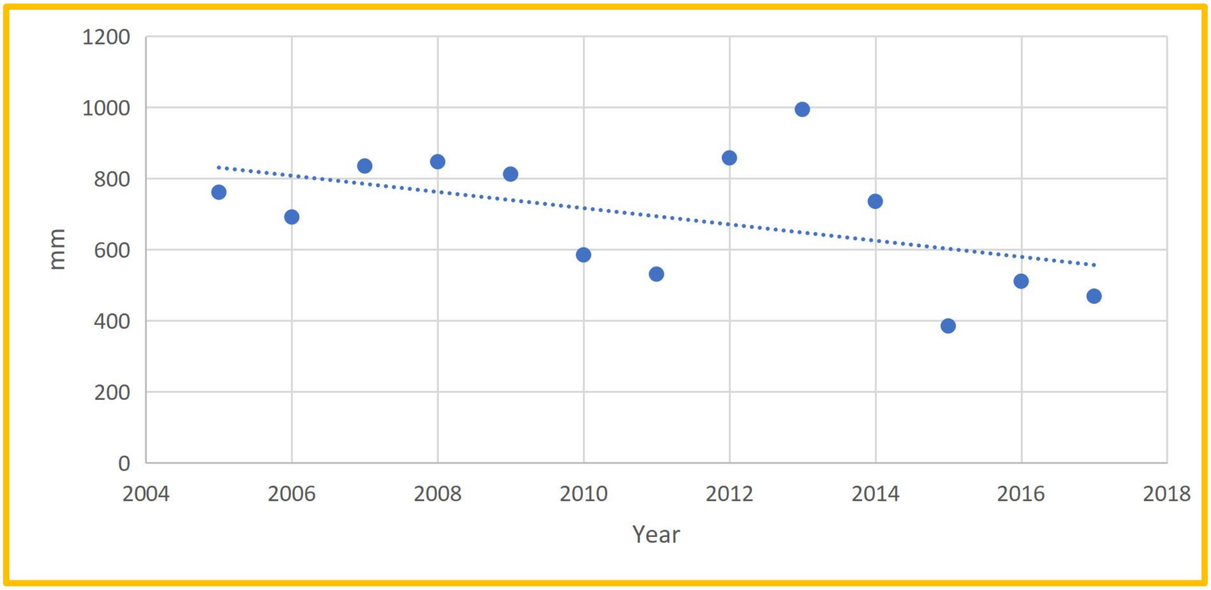


Figure 5- 2: Historical rainfall pattern for the last 10-years

The monthly inflow was calculated by multiplying the precipitation for each month with the total area of the parking lot, water laboratory roof and structures laboratory roof. The monthly rainfall was taken as the available volume for each month, assuming no evaporation takes place (covering of the reservoir will reduce evaporation significantly, although some evaporation may occur in the bio-retention gardens), and all the runoff from the parking lot collects at the stormwater sampling drain. Therefore, a runoff coefficient of 1 was taken, which may be an over assumption, and if application of this technique should be used further investigation is needed.

An Excel spreadsheet can be found in Appendix D2, showing the calculations discussed in the following paragraphs. Figure 5-3 provides an extract from the spreadsheet of the hydrological calculations used to predict the reservoir usage over a 10year period.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
Year	Month	Precipitation (mm)	Precipitation (m)	Parking area m2	Water Lab Area m2	Concrete Lab area m2	Total Area	Monthly inflow = Volume (m3) = Precipitation x area x slope	Reservoir capacity m3	It + I(Delta)t m3	Demand m3	End Volume m3	End capacity m3	100% Demand m3	100% End Volume m3	100% End capacity m3
2004	Aug	37	0.04	12008	4023.50	2568.06	18599.56	688.18	1400	688	512	176	176	614	74	74
	Sep	50.5	0.05	12008	4023.50	2568.06	18599.56	939.28	1400	1115	448	667	667	538	578	578
	Oct	140.6	0.14	12008	4023.50	2568.06	18599.56	2615.10	1400	3283	512	2771	1400	614	2668	1400
	Nov	9	0.01	12008	4023.50	2568.06	18599.56	167.40	1400	1567	384	1183	1183	461	1107	1107
	Dec	5.1	0.01	12008	4023.50	2568.06	18599.56	94.86	1400	1278	128	1150	1150	154	1125	1125

Figure 5- 3: Hydrological study Excel Extract

Firstly, the monthly volume rainfall is calculated as stated above by adding column E, F and G to get the total area value of H, then the volume is calculated by multiplying column H with Column D, Precipitation in meter.

The reservoir capacity was calculated by multiplying the width, length and depth of the proposed reservoir, which was calculated as 1 400m^3. When the reservoir reaches its capacity, the overflow would flow into the drainage system. Column K provides the amount of stormwater cumulated during each month. Column L is 80% of the demand per month, if the reservoir is only used for flushing toilets and not drinking purposes.

The volume in Column M calculates the end volume of each month if only 80% of the demand is met, where the end capacity is the smallest volume between the reservoir capacity and the end volume. The same method was used with the demand at 100% (Column O, P, and Q).

It was found that by using this method, the reservoir would be able to provide 100% of the faculty's water. However, if the declining trend in rainfall, as experienced over the last 10 years, continues, supplementary steps will be required.

A few minor adjustments to the faculties' toilet facilities can reduce the use of water significantly. Most of the bathrooms in the faculty have flushing bowls that take up to 20litres of water, these can be improved by simply putting weights on the rope inside the bowl controlling the flushing handle or placing bricks in the bowls.

5.3.2 Reservoir Design

The size of the reservoir is based on the available space as shown in Figure 5-1. Figure 5-3 shows an image of where the proposed reservoir is located. The preliminary layout of the reservoir can be seen in Figure 5-4, showing the columns, beams and retaining walls. The columns are sized at 500x400x5000mm, the beam sizes are 400x400x7000mm with the column placed in the middle of the beam, reducing the effective length of the beam to 3500mm. The retaining walls are designed as 540mm thick walls, with a base of 3000mm. The slabs are designed to lay on-top of the beams and retaining walls. Calculations and detail layouts can be found in Appendix D.

Figure 5- 4: Proposed Reservoir Location

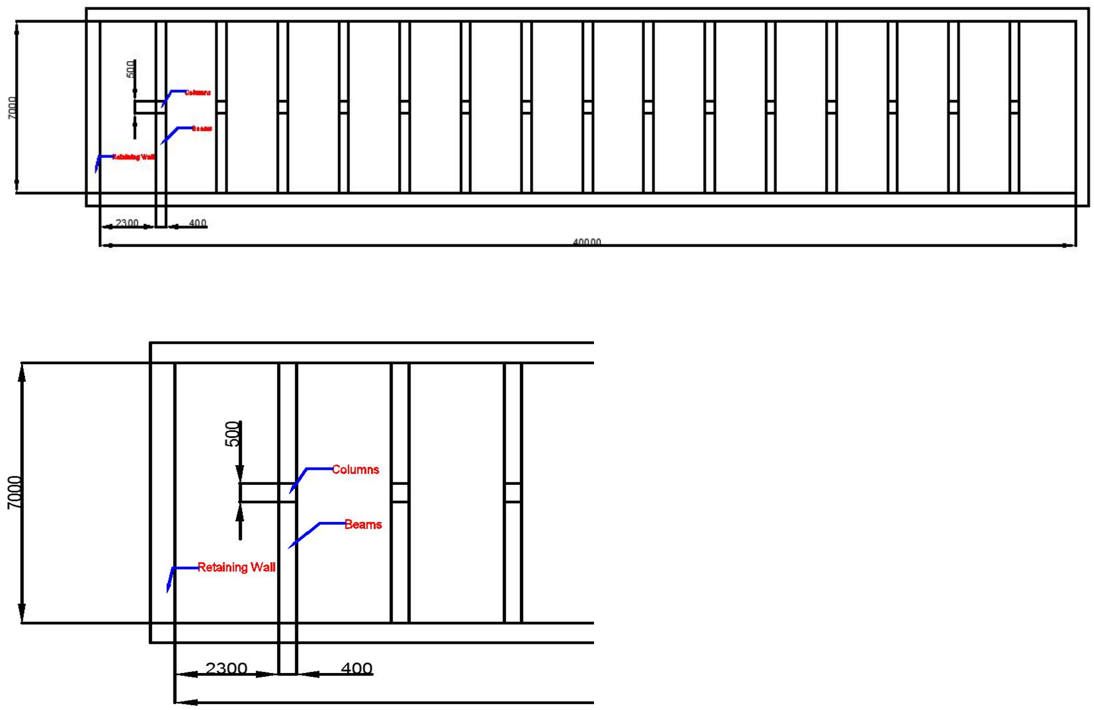


Figure 5- 5: Simple reservoir layout of the Columns, Beams and Retaining Walls

Detailed sections of reservoir can be found in Appendix D.

5.3.2.1 Slab design

If the slabs must carry loads of light construction vehicles, SANS 10160-2 stipulates that the live load carrying capacity of the slab should be $5kN/m^2$. It should also be assumed apart from the dead load of the slab, there would be another layer of pervious material, to reduce the amount of pollutants entering the reservoir.

The slab is broken down into smaller slabs with beams and columns to carry the load, each slab will have an effective length of 3.75m and width of 2.4m. A service entrance to the reservoir should be located closer to the gate of the engineering parking lot.

The calculations and design layout of the slab can be found under Appendix D.

5.3.2.2 Beam design

The beams are located between each section of a slab, with a width of 0.4m and height of 0.4m. The loading on the beams will be the same live load as the slabs, and half of the load of the slabs from each side of the beam. The length of the beams is 7.54m, a column will be placed in the middle of each beam length, which reduces the effective length of the beam to 3.5m.

The calculations and design layout of the beams can be found under Appendix D.

5.3.2.3 Column and footing designs

The columns are placed in the centre of each beam, to reduce the effective length of the beams and reinforcement needed. It would also increase the stability of the structure. Each column is designed to be 0.5mx0.4m in section with a height 5m, with a footing of 1.6mx1.6m. The footing size is dependent on the soil bearing capacity, in this case it was assumed to be 150kPa.

The exact moment on the column was calculated using SANS 10100 standards, as well as Prokon, where the highest moment was used for the design.

The calculations and design layout of the columns and footings can be found under Appendix D.

5.3.2.4 Retaining wall design

The retaining wall is used to support the soil mass on the outer sides of the reservoir to prevent the reservoir from collapsing. The retaining wall designed for this reservoir is rather thick, 540mm. There is a double concrete cavity wall with another concrete wall on the reservoir side of the wall. The footing of the wall is 3m, almost two meters to the soil side, and 0.5m to the reservoir side. The detailed design and calculations of the wall can be found in Appendix D.

5.2.3 Bio-retention garden

Design objectives for the bio-retention garden is to reduce the pollution of the stormwater before entering the reservoir, and overflow stormwater entering the rivers and streams. The garden would also help to reduce the flood peak downstream and enhance ecological values.

No engineering guidelines were found for the design of the bio-retention garden specifically for application in South Africa. However, various aspects were considered, such as the type of pollution, the amount of water to be treated, the retention period, hydrological considerations, climate scenarios etc. A bio-retention garden should be designed to the specifications of the site. If the bio-retention garden is effective enough the water filtering into the reservoir may suitable for potable use.

The water flowing into the system, is only from the parking lot and the roofs of the engineering faculty, which was the water that were tested throughout this study. This provides a good indication of what pollution needs to be treated for in the garden.

Figure 5-5 shows the natural downward flow of the stormwater in the parking lot with the blue arrow, whilst the red lines shows the stormwater drainage system, it is assumed that all the stormwater drains to the South West corner of the parking lot, where the proposed reservoir and bio-retention garden is located.

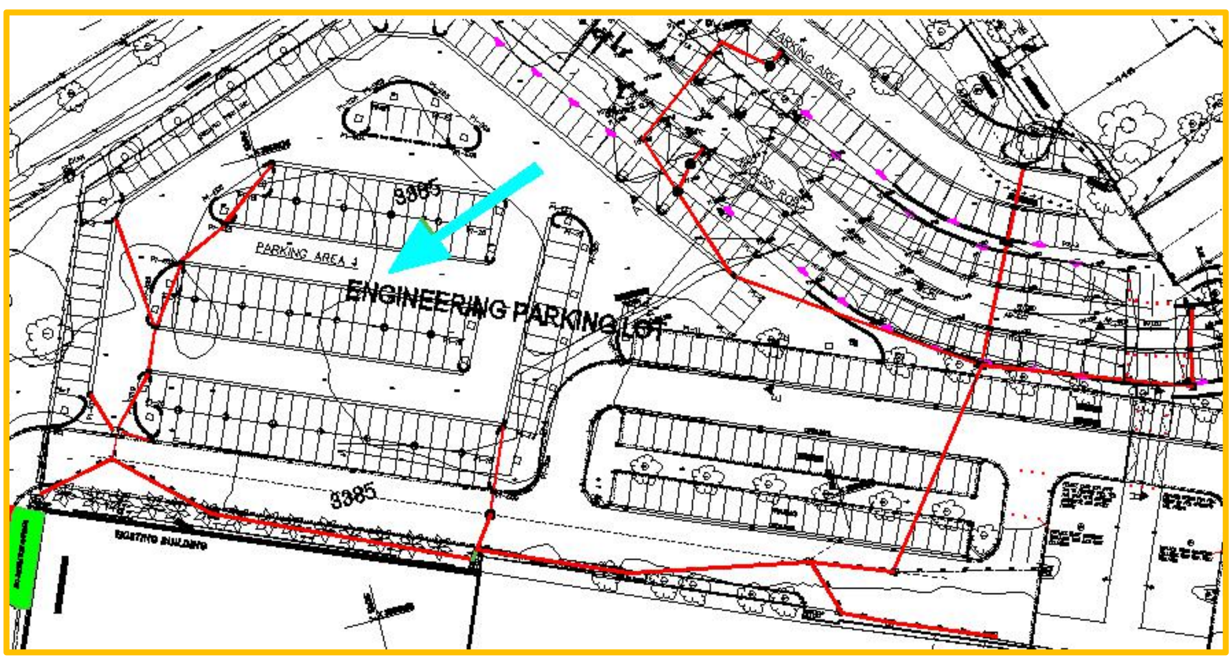


Figure 5- 6: Drainage layout of the Stellenbosch engineering parking lot (Keens, 2011)

Figure 5-7 shows a photograph of where the proposed bio-retention gardens are located. The figure also shows an area where a second bio-filtration garden can be located if the filtration of the stormwater in the proposed garden is not effective enough. Due to time constraints on-site testing for the efficiency of the one garden is not possible.

Figure 5- 7: Proposed bio-retention garden sites

For the design of the bio-retention garden it was assumed that the drainage pipe entering the garden is not more than half a metre underground where it enters the garden. The design layout of the bio-retention garden is shown in Appendix D. There is a small stilling basin for the stormwater entering the garden from the parking lot, to reduce the flood peak of the water, and reduce the sediment by settling in the basin during the rainfall event. The stilling basin will also reduce the maintenance needed after every rainfall event, where the heavier sediment would settle and not distribute into the bio-retention system. The water from the water laboratory roofs would move straight into the garden through the down pipes. Seasonal high-water table position relative to invert is assumed to not intrude into the system.

Bio-retention drainage profile

The drainage profile should provide an environment that is suitable for the plants species to grow, and ensure that the drainage does not adversely affect the surrounding infrastructure, therefore overflow structures are available in the design. The bio-retention surface area calculated from the AutoCad parking lot layout, is 423.175 m^2. Average ponding depth above bio-retention media surface can be up to 450mm. The ponding volume was calculated as approximately 563m^3. The minimum infiltration rate is 12.7mm/hour for an effective bio-retention garden (Kovach, 2012). Using filtration media of sand and loam will provide a filtration rate of 20-30mm/hour (Trojan, 2018) . Therefore, it will be assumed that the filter media is sufficient, but this can only be accepted after the relevant tests are conducted.

The drainage profile consists of a filter media, transition layer, saturated zone, drainage layer, a liner, and at the bottom in-situ soil. On top of the drainage profile a layer of mulch can be placed, this will catch most of the sedimentation, and a lot of the contaminants. The mulch can be replaced after every rainfall season. The type of mulch is dependent on what is available, but shredded hardwood is suggested as a good example. The layers are designed as follows (Kovach, 2012):

- The filter media consist out of sand and loam, 98% sand and 4% fines, the thickness of the layer is 700mm for planting trees.
- The transition layer consists out of less than 2% fines, 15% sand particles that bridge with the larger filter media particles. The sand should be course and washed before being placed. The layer is used as a buffer to prevent the filter media from filtering through to the saturated zone, where the drainage layer is situated.
- The saturated zone consists of fine gravel. It is very important to wash the stone before it is placed, a study conducted at UCT indicated that unwashed stoned can contaminate the stormwater (Biggs, 2016).
- Drainage piping consist of 100mm pipes under the gravel, with a layer of hessian above the drainage layer. The hessian layer will rot away over time, but the soil would have settled by then and not clog the drainage pipe. (Wettenhall, et al., 2014)
- Hydraulic restriction layer (liner) provided

From the results and discussions chapter it was found that Pb is the problematic contaminant in the stormwater and should be reduced. There have been enough studies conducted in South Africa on this subject, but a study conducted in Australia showed that the highest uptake of Pb is reached with a plant species that is also indigenous to South Africa, the *Brassica* family (Tom, et al., 2014). The Brassica family in South Africa is better known as mustard greens, which is also family to cabbage, rapeseed, and radish. Figure 5-8 shows an image of a typical mustard plant.


Figure 5- 8: Mustard green (Wikipedia, n.d.)

Figure 5-9 shows indigenous plant species that can be used for reduction of nutrients in stormwater, these species, Agapanthus, Pennisetum, Stenotaphrum, were identified in a study conducted by University of Cape Town (UCT) (Milandri, et al., 2012).

Figure 5- 9: indigenous plant species best for removal of nutrients

If the ponding volume is reached in the first section of the bio-retention garden, there is an overflow pipe to the bio-retention garden section after the water laboratory delivery door, and if this garden is filled, the stormwater would overflow into the original stormwater canal which runs under the engineering faculty. The water drains through the garden to a collection basin under the ramp of the water laboratory delivery door, into the reservoir. A monitor well is also part of the design for maintenance of the drainage network.

The reservoir must be connected to the current water supply and using pumps when the water is needed.

5.3 Summary

The following information provides a summary of Chapter 5:

- The design can be used as a possible solution to alleviate the pressure on potable water use at the engineering faculty
- The reservoir is a simple design with beams every 2.4m along the reservoir, a column in the middle of each beam length, and retaining walls keeping soil and the pressure of the soil at bay
- It is noted that the design is very preliminary and cannot be used for construction purposes. Soil tests need to be conducted, and the depth of the water table is to be confirmed.
- Geotechnical investigation is required for implementation of the structure.
- If the rainfall trend keeps reducing as indicated in Figure 5-2 the hydraulic study should be re-evaluated, and the need for such designs would become urgent.
- The reservoir designed has a capacity of 1400m^3, which can provide up to 100% of the water demand for the North side of the faculty, if the current demand stays constant, and the rainfall trend does not decrease significantly
- The bio-retention system should be designed specifically for the site.
- It is found that indigenous plant species, Brassica, or better known as mustard seed can significantly reduce Pb in stormwater, but more test needs to be conducted to confirm this.

All the design layouts and calculations can be found in Appendix D.

Chapter 6 : Conclusions and Recommendations

6.1 Introduction

New developments in urban area require relatively high amounts of new data to determine the constituents of stormwater runoff. This is essential for engineers to propose appropriate water quality control measures in their designs of water management structures. Data should be obtained from different land-use types to provide reasonably accurate and valid information for sites still to be developed. To achieve this, significant time and money must be expended on obtaining data from developed sites. If appropriate data is not readily available, engineers may neglect in depth consideration of stormwater quality systems for a development; which can result in polluted water systems downstream of the development.

This study was a starting point in collecting data to help to improve stormwater control structures and management thereof in South Africa. It also attempts to provide insight into practical design applications and how to design according the site specifications.

6.2 Summary of findings

The prime purpose of the research was to establish whether stormwater runoff constituents can be linked to land-use and compare local runoff constituent information / values gathered during the study with international values. It was found that for some of the constituents studied onsite, there was correlation between the data found in the database and the concentrations found in the study site. This indicates, if further investigation with more data is conducted and the same correlations is found, the BMP database can be used as a source for designing purposes.

Throughout the study period, but specifically during the literature research for the project, it was clearly seen that stormwater quality is one of the leading causes of poor water quality in surface waters in South Africa. South African technology that supports stormwater management needs to be improved and developed further to ensure a more sustainable future. With the exponential growth of the population, industrial and climate change, more threats to the natural water are looming.

The concentrations of most of the different metal constituents (As, Cd, Cu, and Zn) observed in the samples, were below the SANS 241 health limit for drinking (potable) water. Pb however showed higher concentrations than the health limit.

The different intensities of the storms influenced the concentrations of the constituents. With high intensity storm events Cd concentrations were high and Cu concentrations were low. With low intensity storm events Cd concentrations were low and Cu concentrations were high. This needs to be investigated further, to establish how much the intensity of storms influences the runoff metals concentrations.

The secondary purpose of the study was to prepare a preliminary design for a stormwater harvesting system at the study site. The design can be used to alleviate potable water shortage, and if adjusted accordingly can be used for different sites and water solutions. The reservoir design can provide almost 100% of the water demand at the faculty – if Pb content can be reduced to below the specified limit for potable water through the proposed bio-retention system. These types of designs should be considered throughout South Africa. With the current decrease/increase in precipitation in most areas in the country, it could alleviate potable water shortage and water pollution problems.

Bio-retention systems are easy to understand but must be designed specifically for each site. It would, however, appear that developers do not have much trust in the systems proposed by environmentalists. This is a global threat to each environmental problem, founded in a lack of education. There are solutions, but people tend to not change their own perspectives easily.

An apt solution for improving stormwater infrastructure is to tax/levy the community in the affected area for stormwater management. Another good measure would be to offer educational programs to communities on how to improve their lives with good housekeeping measures for stormwater management. Taxing should be motivated within the concept of broader water supply security.

Land-use categories were limited to those on which data is adequately available. Many different land-uses exist. Simplification was however required to create smaller data groups for statistical analysis. From literature, the indicated best plant species to be used for the alleviation of Pb pollution in stormwater was the indigenous South African plant called Brassica, or better known as the Mustard plant. This is suggested in the bio-retention garden solution in Chapter 5 (Milandri, et al., 2012).

6.3 Summary of Contributions

The science of stormwater quality must be developed from a valid foundation if the technologies of stormwater quality structures are to grow. This must include valid and usable stormwater constituent data. This project served as a baseline for stormwater data constituents, which can be further developed using the BMP database. This project was only based on a specific land-use type, parking lot and roof, this was related to the BMP database land use types under parking lots for commercial and educational buildings. More data however needs to be obtained for different land uses.

Although stormwater contains many pollutants that may be of concern to human health or the environment, this research covered suspended solids and metals data only. This was primarily due to time and funding limitations.

The design for the bio-retention garden system serves as a contribution for the purification of the runoff. This is based on theory, and should be tested onsite, to introduce more sustainable measures in using water and safeguarding the environment.

6.4 Future Research

Throughout the study many different variables were found to provide the best correlation between the database and onsite data. Due to South Africa's vast range of climates and biodiversity, many different factors need to be considered when comparing data. Factors such as the amount of dry days between storm events, plant life and urban environment, and how the site under consideration is utilised (in this instance a parking lot, with different types of cars, peak and off-peak hours) are required. The year (2017) when the samples were taken, was a very dry year for Cape Town. Therefore, the concentrations may vary when compared to wetter years, summer months, and parking lot usage.

Recommendations for future research questions are:

- What is the impact of different climates (temperature, humidity, rainfall patterns) on different stormwater management systems?
- What is the impact of different ground conditions on the stormwater management systems?
- Which is the most cost-effective stormwater management systems in different urban areas, developed and non-developed areas, for example: city, suburban area, informal settlements or rural areas?
- How can different public buildings (hospitals, hotels, educational buildings, departmental building, etc.) and homes (cluster housing, lose standing houses or apartment building) benefit from stormwater management systems?

- What is the design, financial and maintenance requirements to implement stormwater management systems?
- How will the roots of plants affect the filter media of the bio-retention garden?

6.5 Practical design recommendations

There are many stormwater management tools, but there are no specific guidelines on how to utilise / implement these tools and it is therefore difficult to select the tool that best fits any given area. Therefore, more studies are to be conducted on specific different land use types. These studies need to consider the natural environment and developmental needs of the areas.

Typical design questions for a new development when SuDS will be implemented.

- What are the climatic conditions? Such as temperature, humidity, rainfall patterns. What are the ground conditions? Is extra care needed to the soil for the drainage system to be successful?
  The ground conditions and climatic conditions would provide insight into what type of plant species would best fit the area, is the area polluted to such an extent where material needs to be imported in or is the ground conditions rocky and it would be hard/expensive to construct any drainage infrastructure.
- What is the environment, is it in a city, rural area, informal settlement or suburb? This would provide insight into the type of pollution that would form part of the runoff. For example, informal settlements such as Plankenburg in Stellenbosch has pollution problem of faecal matter and blood, due to not having formal sewage systems and local traditions of slaughtering animals for celebration, where the blood ends up on the street and into the drainage systems.
- What is the water needs of the area where the drainage system would be constructed? If the system could be used for stormwater harvesting, what would the needs be in the area, what size should the storage be to make the system sustainable.
- What is the social impact? Would an educational program have to be implemented to inform the community on how to operate the system? And why it is necessary? Does the area where a SuDS would be implemented need any help from the community, and how would the community be educated in keeping the system running if possible, also creating awareness among people.
- What is the capital available for the drainage system? This would be critical, this provide a limit to the extent of the system.

- What would the maintenance needs be? How can you educate the community to take responsibility and trust in the system?
- Comparing the life-cycle cost of stormwater harvesting and other harvesting systems such as rainwater harvesting and grey water harvesting/reuse.

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Appendices

Appendix A: Raw Data

A1 – Rainfall data

Sample period

Storm Event	Date	Sample Number	Time sample were taken	Periods between sampling (min)	Accumulative period between sampling (min)	Accumulative period between sampling (hours)	Gauge Reading (mm)
1	10.05.2017	1	2:40	0.00	0.00	0.00	0
		2	2:45	5.00	5.00	0.17	1
		3	2:50	10.00	15.00	0.50	2
		4	2:55	15.00	30.00	1.00	3
		5	3:30	45.00	75.00	2.50	3.5
		6	4:00	30.00	105.00	3.50	4
		7	4:30	30.00	135.00	4.50	5
		8	5:00	30.00	165.00	5.50	5.5
		9	5:30	30.00	195.00	6.50	6
		10	6:00	30.00	225.00	7.50	7
Storm Event	Date	Sample Number	Time sample were taken	Periods between sampling (min)	Accumulative period between sampling (min)	Accumulative period between sampling (hours)	Gauge Reading (mm)
2	6.06.17	1	22:40	0.00	0.00	0.00	0
		2	22:45	5.00	5.00	0.17	1
		3	22:55	10.00	15.00	0.50	1.5
		4	23:10	15.00	30.00	1.00	3
		5	0:00	50.00	80.00	2.67	5.5
		6	0:30	30.00	110.00	3.67	9
		7	1:00	30.00	140.00	4.67	10
		8	1:30	30.00	170.00	5.67	10.3
		9	2:00	30.00	200.00	6.67	10.5
		10	2:30	30.00	230.00	7.67	11
Storm Event	Date	Sample Number	Time sample were taken	Periods between sampling (min)	Accumulative period between sampling (min)	Accumulative period between sampling (hours)	Gauge Reading (mm)
3	20.06.2017	1	8:00	0.00	0.00	0.00	2
		2	8:30	30.00	30.00	0.50	2.95
		3	9:00	30.00	60.00	1.00	5.9
		4	11:15	129.00	189.00	3.15	8.85
		5	11:45	30.00	219.00	3.65	11.8
		6	12:15	30.00	249.00	4.15	15.5
		7	12:45	30.00	279.00	4.65	16
		8	13:15	30.00	309.00	5.15	16
		9	13:45	30.00	339.00	5.65	16.1

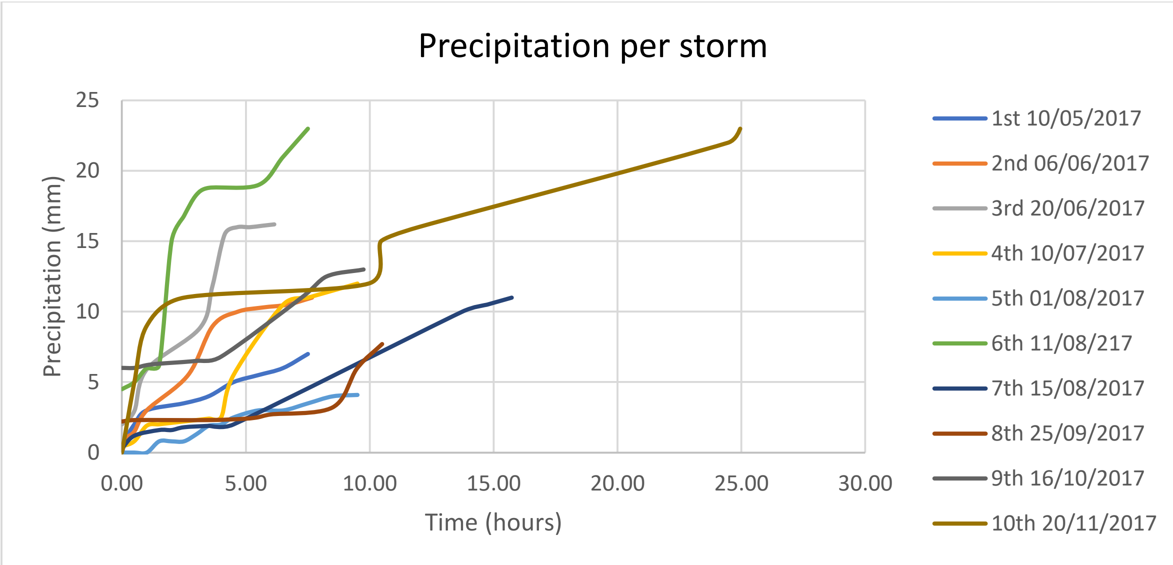
		10	14:15	30.00	369.00	6.15	16.2
Storm Event	Date	Sample Number	Time sample were taken	Periods between sampling (min)	Accumulative period between sampling (min)	Accumulative period between sampling (hours)	Gauge Reading (mm)
4	2017.07.10	1	4:00	0.00	0.00	0.00	0.4
		2	4:30	30.00	30.00	0.50	0.8
		3	5:00	30.00	60.00	1.00	1.9
		4	5:30	30.00	90.00	1.50	2
		5	6:00	30.00	120.00	2.00	2.1
		6	6:30	30.00	150.00	2.50	2.2
		7	7:00	30.00	180.00	3.00	2.3
		8	7:30	30.00	210.00	3.50	2.4
		9	8:00	30.00	240.00	4.00	2.5
		10	8:30	30.00	270.00	4.50	5.5
		11	10:30	120.00	390.00	6.50	10.5
		12	11:30	60.00	450.00	7.50	11
		13	12:30	60.00	510.00	8.50	11.5
		14	13:30	60.00	570.00	9.50	12
Storm Event	Date	Sample Number	Time sample were taken	Periods between sampling (min)	Accumulative period between sampling (min)	Accumulative period between sampling (hours)	Gauge Reading (mm)
5	01.08.2017	1	8:00	0.00	0.00	0.00	0
		2	8:30	30.00	30.00	0.50	0
		3	9:00	30.00	60.00	1.00	0
		4	9:30	30.00	90.00	1.50	0.8
		5	10:00	30.00	120.00	2.00	0.80
		6	10:30	30.00	150.00	2.50	0.80
		7	11:00	30.00	180.00	3.00	1.3
		8	11:30	30.00	210.00	3.50	1.9
		9	12:00	30.00	240.00	4.00	2.00
		10	12:30	30.00	270.00	4.50	2.5
		11	13:30	60.00	330.00	5.50	3.00
		12	14:30	60.00	390.00	6.50	3.00
		13	15:30	60.00	450.00	7.50	3.5
		14	16:30	60.00	510.00	8.50	4
		15	17:30	60.00	570.00	9.50	4.10
Storm Event	Date	Sample Number	Time sample were taken	Periods between sampling (min)	Accumulative period between sampling (min)	Accumulative period between sampling (hours)	Gauge Reading (mm)
6	11.08.2017	1	4:30	0.00	0.00	0.00	4.5
		2	5:00	30.00	30.00	0.50	5
		3	5:30	30.00	60.00	1.00	6
		4	6:00	30.00	90.00	1.50	6.2
		5	6:30	30.00	120.00	2.00	15

		6	7:00	30.00	150.00	2.50	16.8
		7	7:30	30.00	180.00	3.00	18.3
		8	8:00	30.00	210.00	3.50	18.8
		9	10:00	120.00	330.00	5.50	19
		10	11:00	60.00	390.00	6.50	21
		11	12:00	60.00	450.00	7.50	23
Storm Event	Date	Sample Number	Time sample were taken	Periods between sampling (min)	Accumulative period between sampling (min)	Accumulative period between sampling (hours)	Gauge Reading (mm)
7	15.08.2017	1	11:15	0.00	0.00	0.00	0.3
		2	11:45	30.00	30.00	0.50	1.2
		3	12:45	60.00	90.00	1.50	1.6
		4	13:15	30.00	120.00	2.00	1.6
		5	13:45	30.00	150.00	2.50	1.8
		6	14:45	60.00	210.00	3.50	1.9
		7	15:45	60.00	270.00	4.50	2
	16.08.2017	8	10:30	553.50	823.50	13.73	10
		9	11:30	60.00	883.50	14.73	10.5
		10	12:30	60.00	943.50	15.73	11
Storm Event	Date	Sample Number	Time sample were taken	Periods between sampling (min)	Accumulative period between sampling (min)	Accumulative period between sampling (hours)	Gauge Reading (mm)
8	25/09/2017	1	10:00	0.00	0.00	0.00	2.2
		2	10:30	30.00	30.00	0.50	2.3
		3	13:30	180.00	210.00	3.50	2.3
		4	15:00	90.00	300.00	5.00	2.4
		5	15:30	30.00	330.00	5.50	2.5
		6	16:00	30.00	360.00	6.00	2.7
		7	18:30	150.00	510.00	8.50	3.2
		8	20:30	120.00	630.00	9.50	6
						10.50	7.7
Storm Event	Date	Sample Number	Time sample were taken	Periods between sampling (min)	Accumulative period between sampling (min)	Accumulative period between sampling (hours)	Gauge Reading (mm)
9	16.10.2017	1	7:00	0.00	0.00	0.00	6
		2	7:30	30.00	30.00	0.50	6
		3	8:00	30.00	60.00	1.00	6.2
		4	8:30	30.00	90.00	1.50	6.3
		5	10:00	90.00	180.00	3.00	6.5
		6	11:00	60.00	240.00	4.00	6.8
		7	17:30	195.00	435.00	7.25	11
		8	18:30	60.00	495.00	8.25	12.5
		9	20:00	90.00	585.00	9.75	13

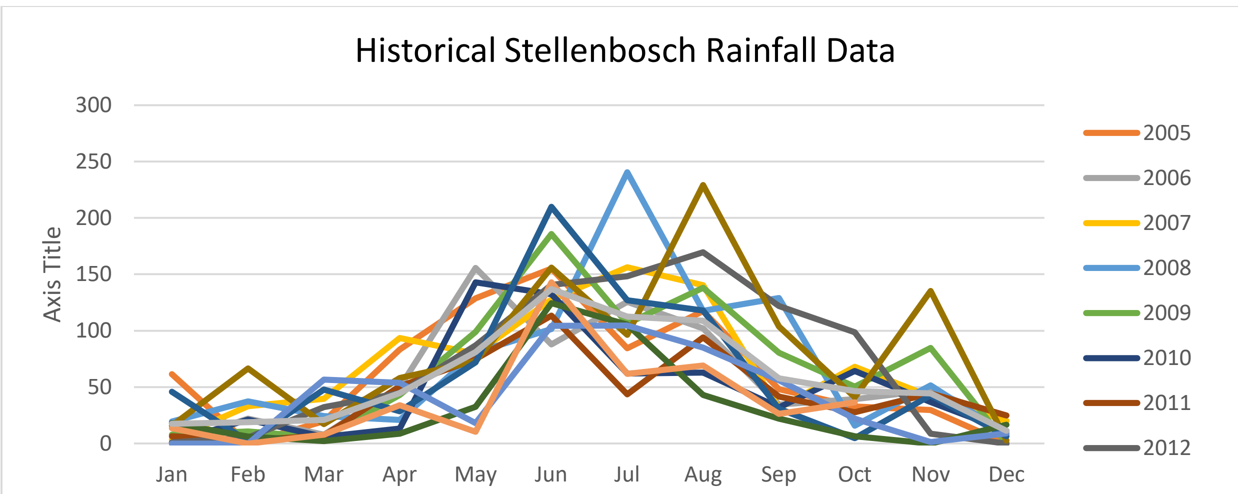
Storm Event	Date	Sample Number	Time sample were taken	Periods between sampling (min)	Accumulative period between sampling (min)	Accumulative period between sampling (hours)	Gauge Reading (mm)
10	20.11.2017	1	22:45	0.00	0.00	0.00	0.00
		2	23:15	30.00	30.00	0.50	5.00
		3	23:45	30.00	60.00	1.00	9
	21.11.2017	4	1:15	90.00	150.00	2.50	11
		5	9:00	447.00	597.00	9.95	12
		6	9:30	30.00	627.00	10.45	15.00
		7	11:00	90.00	717.00	11.95	16.00
		8	22:30	750.00	1467.00	24.45	22
		9	23:00	30.00	1497.00	24.95	23

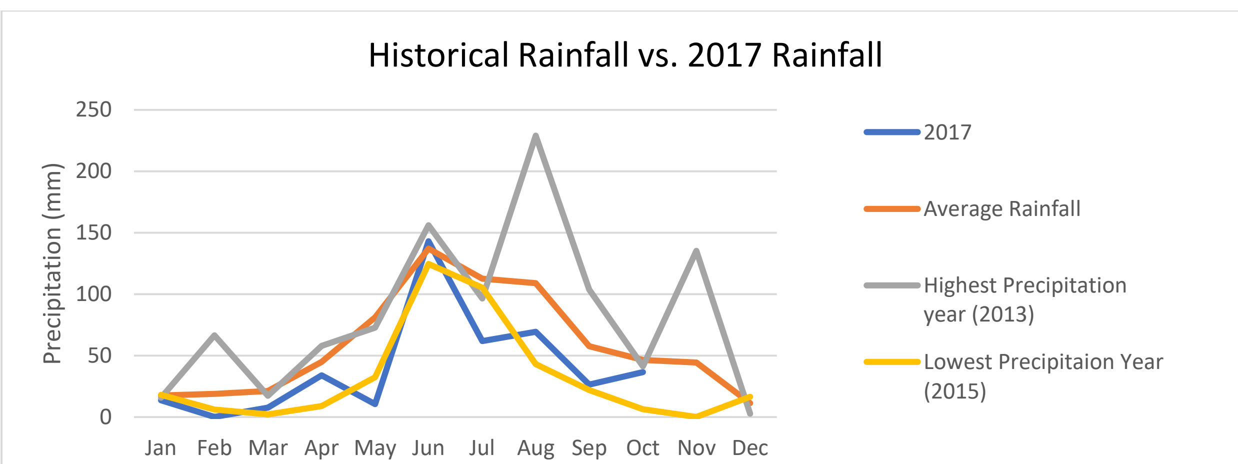
Historical rainfall data (mm)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2005	61.5	0.2	19.7	83.4	128.8	155.1	84.4	117.3	48.2	32.8	29.7	0
2006	0	21.9	7.8	49.8	155.5	87.8	125.6	101.9	34.6	39.2	47.3	20
2007	3.6	33.2	39.7	93.5	79.7	127.6	156.1	140.4	31.3	68.1	41.7	19.9
2008	19.6	37.4	24.3	20.8	80.7	101.3	240.4	117.6	129	15.9	51.4	8.4
2009	7.9	10.7	5.4	43	98.9	185.7	106.4	138	80.5	50.4	84.7	0.3
2010	0.6	21.1	5.8	13.1	142.9	132.3	62	63	32	64.2	36.7	11.2
2011	6.3	3	6.9	50.6	74.7	113.4	43.6	94	41.5	27.6	44.4	24.8
2012	1.1	5.2	32.1	44.6	87	140.7	148.2	169.6	121.8	98.7	8.6	0
2013	15.7	66.5	17.1	57.9	72.7	156	96.4	229	103.7	41.1	135.1	2.7
2014	45.8	2	47.9	28.6	71.8	209.8	126.9	117.9	30.9	4.7	42.8	6.3
2015	18	6	2.2	8.8	32.4	124.4	105.3	43.1	22	6.4	0	16.5
2016	0	0	56.7	53.9	18.1	104.3	104.7	84.9	56	21.9	1.4	8.9
2017	13.5	0	7.7	33.8	10.5	142.9	61.7	69.2	26.4	36.4		
Average	17.6	18.8	21	44.8	81.1	137	112.4	108.8	57.7	46.3	44.4	11.3


Precipitation per storm
Precipitation (mm)
25
20
15
10
5
0
0.00
5.00
10.00
15.00
20.00
25.00
30.00
Time (hours)
1st 10/05/2017
2nd 06/06/2017
3rd 20/06/2017
4th 10/07/2017
5th 01/08/2017
6th 11/08/217
7th 15/08/2017
8th 25/09/2017
9th 16/10/2017
10th 20/11/2017

Historical


Historical Stellenbosch Rainfall Data
Axis Title
300
250
200
150
100
50
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
2005
2006
2007
2008
2009
2010
2011
2012


Historical Rainfall vs. 2017 Rainfall
Precipitation (mm)
250
200
150
100
50
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
2017
Average Rainfall
Highest Precipitation year (2013)
Lowest Precipitaion Year (2015)

A2 – On-site constituent concentrations (µg/L)

Unfiltered As (µg/L)

Sample num.	Sampling day									
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
1	0.52	2.0	0.28	0.22	1.07	0.2	0.20	0.19	0.369	1.04
2	0.46	2.1	0.27	0.28	0.78	0.2	0.20	0.11	0.263	0.56
3	0.35	1.0	0.20	0.40	0.40	0.2	0.20	0.18	0.238	0.14
4	0.32	0.5	0.33	0.40	0.31	0.2	0.20	0.22	0.294	0.18
5	0.31	0.5	0.19	0.23	0.26	0.2	0.20	0.22	0.401	0.31
6	0.40	0.5	0.20	0.15	0.10	0.2	0.20	0.17	0.415	0.18
7	0.41	0.5	0.28	0.27	0.25	0.2	0.20	0.15	0.456	0.34
8	0.46	0.5	0.13	0.23	0.22	0.2	0.20	0.39	0.206	0.49
9	0.27	0.5	0.15	0.24	0.20	0.2	0.20	0.18	0.283	0.18
10	0.11	0.5	0.18	0.16	0.17	0.2	0.20	0.27	0.325	0.378

Filtered As (µg/L)

Sample num.	Sampling day									
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
1	0.59166	0.96	0.24	0.20	1.09	0.2	0.20	0.31	0.391	0.90
2	0.443479	0.62	0.27	0.21	0.81	0.2	0.20	0.18	0.265	0.46
3	0.395302	0.36	0.19	0.43	0.40	0.2	0.20	0.29	0.286	0.21
4	0.303532	0.23	0.26	0.40	0.31	0.2	0.20	0.25	0.342	0.24
5	0.339187	0.11	0.22	0.26	0.16	0.2	0.20	0.3	0.477	0.25
6	0.393506	0.11	0.17	0.21	0.19	0.2	0.20	0.15	0.412	0.24
7	0.424571	0.11	0.11	0.32	0.39	0.2	0.20	0.16	0.355	0.38
8	0.496714	0.13	0.11	0.17	0.14	0.2	0.20	0.36	0.190	0.36
9	0.250201	0.20	0.17	0.11	0.10	0.2	0.20	0.23	0.216	0.20
10	0.106009	0.21	0.17	0.18	0.16	0.20	0.20	0.34	0.326	0.362

Suspended As (µg/L)

Sample num.	Sampling day									
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
1	0.00	1.05	0.04	0.02	0.00	0.00	0.00	0.00	0.00	0.13
2	0.02	1.52	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.09
3	0.00	0.64	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.01	0.27	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.39	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.06
6	0.01	0.39	0.03	0.00	0.00	0.00	0.00	0.02	0.00	0.00
7	0.00	0.39	0.17	0.00	0.00	0.00	0.00	0.00	0.10	0.00
8	0.00	0.37	0.02	0.06	0.08	0.00	0.00	0.03	0.02	0.13
9	0.02	0.30	0.00	0.13	0.10	0.00	0.00	0.00	0.07	0.00
10	0.00	0.29	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.02

Unfiltered Cd (µg/L)

Sample num.	Sampling day									
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
1	0.21	0.47	0.33	0.24	0.41	0.10	0.21	0.03	0.088	0.19
2	0.06	0.39	0.51	0.35	0.25	0.10	0.48	0.03	0.073	0.06

3	0.06	0.39	0.26	0.56	0.19	0.22	0.10	0.03	0.068	0.01
4	0.05	0.44	0.90	0.54	0.09	0.35	0.96	0.06	0.084	0.03
5	0.05	0.22	0.40	0.35	0.21	0.10	0.42	0.07	0.093	0.06
6	0.07	0.12	0.44	0.23	0.06	0.10	0.46	0.04	0.109	0.05
7	0.09	0.31	0.19	0.37	0.05	0.18	0.02	0.02	2.057	0.09
8	0.09	0.25	0.17	0.34	0.09	0.44	0.18	0.06	0.076	0.32
9	0.09	0.83	0.42	0.31	0.08	0.31	0.10	0.03	0.092	1.15
10	0.02	0.34	0.40	0.14	0.08	0.26	0.10	0.03		

Filtered Cd (µg/L)

Sample num.	Sampling day									
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
1	0.218323	0.46	0.87	0.95	0.74	0.1	0.24	0.03	0.098	0.17
2	0.048287	0.31	0.55	0.54	0.48	0.1	0.51	0.02	0.081	0.07
3	0.038117	0.63	0.90	0.64	0.16	0.1	0.10	0.05	0.101	0.06
4	0.031215	0.65	0.60	0.46	0.25	0.124673	0.10	0.07	0.139	0.05
5	0.048472	0.27	0.56	0.74	0.40	0.098967	0.15	0.09	0.138	0.05
6	0.049636	0.30	0.59	0.60	0.32	0.1	0.13	0.04	0.107	0.05
7	0.076128	0.27	0.57	0.85	0.29	0.230072	0.10	0.05	0.150	0.08
8	0.077123	0.32	0.45	0.41	0.17	0.20822	0.10	0.09	0.051	0.32
9	0.062929	0.38	0.46	0.48	0.25	0.120175	0.10	0.05	0.074	1.14
10	0.023764	0.20	0.68	0.64	0.17		0.10	0.05		

Suspended Cd (µg/L)

Sample num.	Sampling day									
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
1	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
2	0.01	0.08	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
3	0.02	0.00	0.00	0.00	0.03	0.12	0.00	0.00	0.00	0.00
4	0.02	0.00	0.30	0.08	0.00	0.22	0.86	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.00	0.01
6	0.02	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00
7	0.02	0.04	0.00	0.00	0.00	0.00	0.00	0.00	1.91	0.01
8	0.02	0.00	0.00	0.00	0.00	0.23	0.09	0.00	0.03	0.00
9	0.03	0.45	0.00	0.00	0.00	0.19	0.00	0.00	0.02	0.01
10	0.00	0.14	0.00	0.00	0.00	0.26	0.00	0.00	0.00	0.00

Unfiltered Cu (µg/L)

Sample num.	Sampling day									
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
1	7.11	21.0	18.08	10.46	22.83	1.12	2.31	4.39	4.170	12.36
2	4.10	21.5	6.36	37.44	16.71	0.47	2.86	1.54	2.825	4.76
3	4.19	30.0	6.17	18.97	9.34	0.71	1.41	2.16	3.301	1.30
4	3.14	8.0	36.15	18.01	5.13	0.83	0.69	3.17	3.952	1.46
5	13.48	29.6	12.44	12.03	5.11	0.81	4.34	2.77	4.411	3.53
6	5.91	7.4	7.06	9.61	10.28	0.22	3.23	1.84	5.219	1.46
7	5.22	34.0	6.76	33.37	4.28	0.50	0.96	1.94	17.172	3.62
8	5.32	10.1	18.36	13.11	18.51	1.17	0.49	3.74	3.029	6.53
9	4.48	25.2	16.18	12.65	22.46	2.09	0.46	1.51	7.809	2.43
10	1.88	31.8	41.36	5.90	2.39	1.27	0.69	2.19		

Filtered Cu (µg/L)

Sample num.	Sampling day									
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
1	9.56	17.43	20.84	21.27	11.60	1.48	2.30	5.07	5.93	10.89
2	4.69	8.56	17.95	39.82	7.73	0.46	1.23	1.84	5.37	5.28
3	5.42	9.78	15.30	24.28	3.08	0.66	1.75	2.61	5.48	3.53
4	3.57	7.08	9.59	13.58	3.16	1.25	0.79	3.41	6.70	4.81
5	14.48	10.20	13.81	41.08	1.88	0.67	5.66	3.11	5.86	3.14
6	5.28	3.72	51.58	42.61	1.10	0.13	1.58	1.70	6.64	2.36
7	5.77	7.74	6.12	23.60	2.13	0.43	1.04	2.22	6.82	3.76
8	6.02	3.83	4.86	13.28	1.02	0.38	0.29	3.83	4.89	5.04
9	4.58	10.15	17.54	9.30	1.18	0.77	0.47	2.58	2.00	2.71
10	1.78	6.79	6.91	40.36	1.12		0.66	2.97		0.00

Suspended Cu (µg/L)

Sample num.	Sampling day									
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
1	0	3.543714	0	0	11.23204	0	0.0041	0	0	1.470299
2	0	12.98495	0	0	8.979555	0.0036	1.631	0	0	0
3	0	20.21749	0	0	6.261695	0.04719	0	0	0	0
4	0	0.920704	26.56135	4.422553	1.976509	0	0	0	0	0
5	0	19.36741	0	0	3.230464	0.13996	0	0	0	0.386146
6	0.625	3.694707	0	0	9.189905	0.0868	1.65	0.14	0	0
7	0	26.25574	0.634012	9.772896	2.147041	0.0692	0	0	10.35068	0
8	0	6.272573	13.49803	0	17.48619	0.78408	0.203	0	0	1.483511
9	0	15.08562	0	3.346256	21.27524	1.31707	0	0	5.812932	0
10	0.0921	25.05499	34.45085	0	1.264097		0.0286	0		0

Unfiltered Pb (µg/L)

Sample num.	Sampling day									
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
1	4.41	11.0	3.52	6.76	25.71	0.77	0.71	4.71	5.583	22.82
2	1.88	20.5	4.71	6.80	12.73	0.69	0.11	2.92	6.963	21.15
3	1.77	7.3	2.97	4.12	5.48	0.30	0.40	3.95	3.067	3.69
4	1.19	5.1	3.58	7.64	3.96	0.31	0.18	1.97	2.908	3.48
5	0.63	4.0	3.21	3.71	4.01	9.49	0.26	3.65	7.569	32.31
6	1.24	2.6	3.37	1.91	3.62	1.31	0.40	3.54	4.314	3.68
7	1.12	2.3	3.39	3.82	2.99	1.44	0.50	2.69	29.988	5.51
8	1.39	2.1	3.22	3.66	4.90	0.22	0.71	12.64	15.728	318.63
9	4.09	2.6	3.40	4.66	4.65	0.35	0.25	1.47	3.752	20.08
10	0.39	2.2	4.01	5.85	6.07	0.41	0.25	1.31		

Filtered Pb (µg/L)

Sample num.	Sampling day									
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
1	11.47467	6.13	2.10	1.04	7.95	0.781268	0.71	3.47	4.995	1.38
2	4.110067	4.02	3.79	2.76	4.07	0.700673	0.25	2	4.838	12.32

3	3.452384	1.24	1.37	1.57	1.84	0.296408	0.45	2.99	2.363	3.05
4	1.874222	1.11	1.42	3.98	1.32	0.746328	0.19	1.46	3.049	2.53
5	1.620194	0.44	1.24	1.88	1.14	9.297011	0.25	3.23	5.469	19.46
6	2.093441	0.47	3.28	0.98	0.89	1.251576	0.42	2.35	2.886	2.44
7	2.696935	0.47	1.48	1.54	1.04	1.541313	0.49	1.69	19.614	4.22
8	3.124118	0.47	0.87	1.10	1.33	0.25	0.59	7.53	10.212	210.79
9	8.009547	0.45	1.03	1.75	1.26	0.26782	0.25	0.63	4.123	12.27
10	0.874662	0.61	0.86	6.14	2.06		0.25	0.36		

Suspended Pb (µg/L)

Sample num.	Sampling day									
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
1	0.00	4.87	1.42	5.71	17.75	0.00	0.00	1.24	0.59	21.44
2	0.00	16.52	0.92	4.04	8.66	0.00	0.00	0.92	2.13	8.82
3	0.00	6.10	1.60	2.56	3.63	0.01	0.00	0.96	0.70	0.65
4	0.00	4.03	2.16	3.65	2.64	0.00	0.00	0.51	0.00	0.95
5	0.00	3.59	1.97	1.83	2.86	0.19	0.01	0.42	2.10	12.85
6	0.00	2.16	0.09	0.93	2.73	0.06	0.00	1.19	1.43	1.24
7	0.00	1.86	1.92	2.28	1.96	0.00	0.01	1.00	10.37	1.29
8	0.00	1.59	2.35	2.56	3.57	0.00	0.12	5.11	5.52	107.84
9	0.00	2.13	2.37	2.91	3.39	0.08	0.00	0.84	0.00	7.81
10	0.00	1.56	3.15	0.00	4.01	0.41	0.00	0.95	0.00	0.00

Unfiltered Zn (µg/L)

Sample num.	Sampling day									
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
1	482	1522	413	310	2348	288	425	258	769.327	1583.47
2	357	1134	460	369	1357	299	258	258	566.108	398.32
3	324	512	339	809	480	450	356	369	608.023	150.24
4	284	264	509	927	458	478	278	503	707.610	353.82
5	442	316	317	368	420	128	418	749	686.195	403.53
6	497	362	221	301	351	209	448	312	769.182	491.31
7	587	192	342	1025	441	321	521	340	460.423	760.14
8	631	449	280	349	266	375	429	338	201.938	1456.72
9	498	717	272	166	347	259	475	314	679.047	329.19
10	169	701	346	168	349	312	383	444		

Filtered Zn (µg/L)

Sample num.	Sampling day									
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
1	483.7015	1338	598	425	2354	308.2687	425	272	799.488	1379.13
2	337.3512	957	656	538	1406	302.7813	257	309	517.451	369.36
3	318.6514	448	491	1116	486	463.5323	362	422	613.660	177.94
4	274.3084	232	710	1262	477	509.2083	280	553	714.034	413.16
5	405.6457	256	445	528	380	129.6484	413	758	805.402	369.92
6	480.097	323	321	431	368	212.0271	419	256	672.930	512.83
7	560.5494	177	490	1435	482	329.3614	505	315	422.546	750.91
8	581.4597	426	378	486	286	381.4907	403	334	200.863	1430.37
9	460.6287	598	376	230	350	249.4434	485	338	644.550	299.38
10	181.6188	586	484	253	415		388	487		

Suspended Zn (µg/L)

Sample num.	Sampling day									
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
1	0	183	0	0	0	0	0	0	0	204
2	19	176	0	0	0	0	0	0	49	29
3	5	64	0	0	0	0	0	0	0	0
4	10	31	0	0	0	0	0	0	0	0
5	36	61	0	0	39	0	5	0	0	34
6	17	39	0	0	0	0	30	56	96	0
7	26	16	0	0	0	0	16	25	38	9
8	49	23	0	0	0	0	26	4	1	26
9	37	119	0	0	0	9	0	0	34	30
10	0	115	0	0	0	312	0	0	0	0

VSS- TSS – ISS Raw Data

Date	Sample num	amount water	time	pipe	precipitation mm	weight of filter	weight of porcelain	weight after oven	filter after oven	weight after furnace	weight of paper after furnace	TSS with porcelain	TSS updated	TSS only filter	oven-porcelain -fil	fur-porcelain -fil	oven (mg/L)	Fur (mg/L)
01.08.17	1	425	8:00	1	-	0.372	22.273	22.655	0.383	22.648	0.377	0.023529	0.023529	0.025882	0.01	0.003	0.023529	0.007059
	2	540	8:30	-	-	0.367	22.065	22.437	0.374	22.435	0.369	0.009259	0.009259	0.012963	0.005	0.003	0.009259	0.005556
	3	575	9:00	15	-	0.366	20.474	20.857	0.377	20.851	0.372	0.029565	0.029565	0.019130	0.017	0.011	0.029565	0.019130
	4	540	9:30	15	0.8	0.372	22.517	22.887	0.372	22.884	0.374	-0.00370	-0.00370	0	-0.002	-0.005	-0.00370	-0.00926
	5	650	10:00	20		0.37	23.203	23.573	0.375	23.573	0.37	1.54E-15	0	0.007692	9.99E-16	9.99E-16	1.54E-15	1.54E-15
	6	500	10:30	10		0.372	22.492	22.871	0.372	22.867	0.371	0.014	0.014	0	0.007	0.003	0.014	0.006
	7	575	11:00	10	1.3	0.372	22.19	22.562	0.372	22.921	0.375	-1.93E-16	0	0	0	0.359	0	0.624348
	8	480	11:30	-	1.9	0.371	22.546	22.919	0.373	22.917	0.37	0.004167	0.004167	0.004167	0.002	2.22E-15	0.004167	4.626E-15
	9	525	12:00	10		0.371	22.814	23.184	0.372	23.181	0.367	-0.00190	-0.00190	0.001905	-0.001	-0.004	-0.00190	-0.00762
	10	600	12:30	10	2.5	0.369	22.273	22.644	0.369	22.641	0.37	0.003333	0.003333	0	0.002	-0.001	0.003333	-0.00167
	11	460	13:30			0.373	22.273	22.961	0.37	22.962	0.371	0.684783	0.684783	0	0.315	0.316	0.684782	0.686956
	12	460	14:30			0.369	22.187	23.183	0.371	22.983	0.392	1.363043	1.363043	0.004348	0.627	0.427	1.363043	0.928261
	13	475	15:30	30	3.5	0.37	22.545	22.89	0.374	22.643	0.369	-0.0526	-0.05263	0.008421	-0.025	-0.272	-0.05263	-0.57263
	14	450	16:30		4	0.372	22.816	22.812	0.372	22.916	0.37	-0.83556	-0.83556	0	-0.376	-0.272	-0.83556	-0.60444
	15	475	17:30	10		0.375	22.514	23.513	0.373	23.18	0.7	1.313684	1.313684	0	0.624	0.291	1.313684	0.612632
11.08.17	1	380	4:30	50	4.5	0.37	22.812	23.182	0.37	23.183	0.371	-6.72E-15	0	0	-2.6E-15	0.001	-6.72E-15	0.002632
	2	425	5:00	50	5	0.369	22.545	22.926	0.381	22.915	0.369	0.028235	0.028235	0.028235	0.012	0.001	0.028235	0.002353
	3	430	5:30	10	6	0.368	22.186	22.563	0.377	22.562	0.371	0.020930	0.020930	0.020930	0.009	0.008	0.020930	0.018605
	4	375	6:00	10	6.2	0.372	22.497	22.871	0.374	22.867	0.373	0.005333	0.005333	0.005333	0.002	-0.002	0.005333	-0.00533
	5	400	6:30	100	15	0.365	22.065	22.436	0.371	22.434	0.369	0.015	0.015	0.015	0.006	0.004	0.015	0.01
	6	350	7:00	20	16.8	0.373	22.271	22.644	0.377	22.644	0.369	3.172E-15	0	0.011426	1.11E-15	1.11E-15	3.171E-15	3.171E-15
	7	400	7:30	15	18.3	0.368	22.596	22.964	0.37	22.961	0.37	-3.61E-15	0	0.005	-1.4E-15	-0.003	-3.61E-15	-0.0075
	8	410	8:00	5	18.8	0.372	22.592	22.962	0.368	22.964	0.372	-0.00488	-0.00488	0	-0.002	0	-0.00488	0
	9	400	10:00		19	0.375	22.273	22.647	0.374	22.643	0.37	-0.0025	-0.0025	0	-0.001	-0.005	-0.0025	-0.0125
	10	525	11:00	5	21	0.369	23.201	23.572	0.371	23.567	0.67	0.003809	0.003809	0.003809	0.002	-0.003	0.003809	-0.00571
	11	505	12:00	100	23	0.37	20.478	20.845	0.365	20.844		-0.00594	-0.00594	0	-0.003	-0.004	-0.00594	-0.00792
15.08.17	1	400	11:15	10	0.3	0.364	22.502	22.869		22.865	0.365	0.0075	0.0075	0	0.003	-0.001	0.0075	-0.0025
	2	430	11:45		1.2	0.374	22.546	22.919	0.373	22.914	0.372	-0.00233	-0.00233	0	-0.001	-0.006	-0.00233	-0.01395
	3	420	12:45	10	1.6	0.368	22.19	22.559	0.369	22.557	0.367	0.002381	0.002381	0.002381	0.001	-0.001	0.002381	-0.00238
	4	390	13:15	5	1.6	0.374	22.813	23.186	0.372	23.186	0.374	-0.00256	-0.00256	0	-0.001	-0.001	-0.00256	-0.00256
	5	280	13:45	5	1.8	0.365	22.498	22.865	0.367	22.863	0.367	0.007143	0.007143	0.007143	0.002	-1.6E-15	0.007143	-5.55E-15
	6	425	14:45	5	1.9	0.364	23.2	23.57	0.368	23.569	0.366	0.014118	0.014118	0.009412	0.006	0.005	0.014118	0.011765
	7	435	15:45	10	2	0.367	22.516	22.885	0.369	22.883	0.368	0.004598	0.004598	0.004598	0.002	8.88E-16	0.004598	2.042E-15
16.08.17	8	430	10:30	30	-	0.365	20.476	20.852	0.374	20.85	0.37	0.025581	0.025581	0.020930	0.011	0.009	0.025581	0.020930
	9	380	11:30	5	10.5	0.372	22.066	22.437	0.371	22.434	0.371	-0.00263	-0.00263	0	-0.001	-0.004	-0.00263	-0.01053
	10	330	12:30	2	11	0.368	22.592	22.96	0.368	22.957	0.366	6.392E-15	0	0	2.11E-15	-0.003	6.392E-15	-0.00909
															0	0		
16.10.17	1	485	7:00	20	6		22.191	22.562		22.561	0.37	0.764948	0.764948	0	0.371	0.37	0.764948	0.762887

	2	500	7:30	20	-	0.372	22.546	22.921		22.92	0.37	0.006	0.006		0.003	0.002	0.006	0.004
	3	480	8:00		6.2	0.369	20.479	20.848		20.848	0.372	-4.63E-16	0		0	0	0	0
	4	480	8:30		-	0.368	22.066	22.885		22.881	0.368	0.939583	0.939583		0.451	0.447	0.939583	0.93125
	5	550	10:00	5	6.5	0.372	22.813	23.191		23.184	0.372	0.010909	0.010909		0.006	-0.001	0.010909	-0.00182
	6	505	11:00	-	6.8	0.367	22.518	22.432		22.433	0.368	-0.89703	-0.89703		-0.453	-0.452	-0.89703	-0.89505
	7	650	17:30	-	11	0.366	23.201	23.603		23.58	0.38	0.055385	0.055385		0.036	0.013	0.055385	0.02
	8	460	18:30	150	12.5	0.372	22.272	22.656		22.652	0.379	0.026087	0.026087		0.012	0.008	0.026087	0.017391
	9	250	20:00		13	0.368	22.593	22.96		22.961	0.368	-0.004	-0.004		-0.001	-1.4E-15	-0.004	-5.77E-15
25.10.17	1	725	10:00	-		0.367	22.065	22.433	0.367	22.432		0.001379	0.001379	0	0.001	-2.7E-15	0.001379	-3.67E-15
	2	730	10:15	-		0.366	22.516	22.88	0.365	22.888	0.374	-0.00274	-0.00274	0	-0.002	0.006	-0.00274	0.008219
	3	650	10:45	-		0.367	22.813	23.18	0.369	23.183	0.372	1.366E-15	0	0.003077	8.88E-16	0.003	1.366E-15	0.004615
	4	675	11:15	-	1.7	0.371	22.546	22.921	0.372	22.92		0.005926	0.005926	0.001481	0.004	0.003	0.005926	0.004444
	5	700	11:45	-	3	0.372	22.188	22.557	0.367	22.559	0.366	-0.00428	-0.00428	0	-0.003	-0.001	-0.00429	-0.00143
	6	725	12:30	-	5	0.369	22.499	22.868	0.369	22.646	0.371	-3.06E-16	0	0	0	-0.222	0	-0.30621
	7	650	13:00	-		0.369	23.201	23.571	0.369	23.567	0.367	0.001538	0.001538	0	0.001	-0.003	0.001538	-0.00462
	1	455	10:00	20	2.3	0.37	20.474	20.851	0.374	20.848	0.373	0.015385	0.015385	0.008791	0.007	0.004	0.015385	0.008791
	2	450	10:30	10	2.3	0.372	22.062	22.437	0.373	22.437	0.373	0.006667	0.006667	0.002222	0.003	0.003	0.006667	0.006667
	3	450	13:30		2.4	0.369	22.519	22.89	0.371	22.883	0.369	0.004444	0.004444	0.004444	0.002	-0.005	0.004444	-0.01111
	4	440	15:00		2.7	0.369	22.813	23.186	0.372	23.181	0.372	0.009091	0.009091	0.006818	0.004	-0.001	0.009091	-0.00227
	5	430	15:30		3.2	0.367	22.546	22.919	0.37	22.916	0.37	0.013953	0.013953	0.006977	0.006	0.003	0.013953	0.006977
	6	450	16:00		4.4	0.369	22.191	22.56	0.37	22.559	0.366	-4.93E-16	0	0.002222	0	-0.001	0	-0.00222
	7	375	18:30			0.371	22.497	22.868	0.373	22.869	0.372	-3.55E-15	0	0.005333	-1.3E-15	0.001	-3.55E-15	0.002667
	8	400		20	6	0.372	22.274	22.644	0.371	22.636	0.365	-0.005	-0.005	0	-0.002	-0.01	-0.005	-0.025
	9	380	20:30	150	7.7	0.369	22.592	22.964	0.373	22.96	0.36	0.007895	0.007895	0.010526	0.003	-0.001	0.007895	-0.00263
20.11.17	1	470	22:45			0.366	23.203	23.574	0.372	23.574	0.372	0.010638	0.010638	0.012766	0.005	0.005	0.010638	0.010638
	2	550	23:15			0.371	20.477	20.846	0.373	20.846	0.369	-0.00364	-0.00364	0.003636	-0.002	-0.002	-0.00364	-0.00364
	3	450	23:45	full	9	0.366	22.065	22.433	0.371	22.433	0.37	0.004444	0.004444	0.011111	0.002	0.002	0.004444	0.004444
21.11.17	4	500	1:15	30	11	0.368	22.499	23.031	0.636	23.031	0.535	0.328	0.328	0.536	0.164	0.164	0.328	0.328
	5	500	9:00			0.368	22.59	22.885	0.372	22.885	0.369	-0.146	-0.146	0.008	-0.073	-0.073	-0.146	-0.146
	6	490	9:30			0.369	22.273	22.561	0.373	22.561	0.37	-0.16531	-0.16531	0.008163	-0.081	-0.081	-0.16531	-0.16531
	7	550	11:00			0.368	23.199	23.572	0.37	23.57	0.37	0.00909091	0.00909091	0.00363636	0.005	0.003	0.00909091	0.00545455
	8	550	22:30	full	22	0.369	20.429	20.848	0.372	22.964	0.371	0.090909	0.090909	0.005455	0.05	2.166	0.090909	3.938182
	9	510	23:00		23	0.37	22.515	22.883	0.368			-0.00392	-0.00392	0	-0.002	-22.885	-0.00392	-44.8725

A3 – BMP data used

Total As

Denver Wastewater Building	I-5/SR-78 P&R	La Costa P&R	Lakeview 2	Lakeview 4	Lakewood P&R	Lakeview Shops	Termination P&R	Via Verde P&R	On-Site Data	WQ Units
3.8	0.83	7	0.8	4.4	1	1.4	1.1	0.5	0.358113383	µg/L
1	2	0.5	1	3.3	0.7	0.5	0.5	1.8	0.831715803	µg/L
1	0.78	0.9	1	3	0.9	3	0.8	0.5	0.238615332	µg/L
1	1	1.1	2.5	4.1	4.8	1	2.5	0.5	0.234439923	µg/L
6	7.7	0.98	1.5	2.6	3.2	1.1	1.1	0.7	0.397044806	µg/L
1	1.6	0.5	0.8	3.8	0.6	1	1.3	1	0.2	µg/L
1	1.6	2.2	2.7	4.6	0.7	1	0.5	0.5	0.2	µg/L
3.9	2.5	2.5	0.9	3.7	0.9	2.5	0.5	0.5	0.233376623	µg/L
6.7	1.6	0.5	0.7	2.5	0.8	1	0.8		0.372220777	µg/L
1	2.4	0.98	0.8	2.5	1.4	2.6	0.6		0.347980885	µg/L
3.7	1	1.1	0.6	3	1.2	1				µg/L
2.5	1.2	0.75	0.5		2	1				µg/L
2.5	2.5	0.65	0.5			1				µg/L
2.5	2	1.9	4			1				µg/L
2.5	1.2	1.2	2.2			1				µg/L
2.5	5.9	1.4	1.2			1.4				µg/L
2.5	0.73	1.7	1.1			1.3				µg/L
2.5	0.83	7.6	0.9			1.8				µg/L
2.5	0.58		0.9			1.1				µg/L
2.5	2.9		0.9			1.4				µg/L
2.5	1		1			1.4				µg/L
2.5	0.9		1			0.5				µg/L
2.5			0.6			0.5				µg/L
2.5			0.5			1.1				µg/L
2.5			0.8			3.1				µg/L
2.5			0.5			1.9				µg/L
2.5			0.7			0.5				µg/L
2.5			0.7			1				µg/L
2.5			0.4			1				µg/L
2.5			0.8			1				µg/L
2.5			1			1				µg/L

Total As

Denver Wastewater Building	I-5/SR-78 P&R	La Costa P&R	Lakeview 2	Lakeview 4	Lakewood P&R	Lakeview Shops	Termination P&R	Via Verde P&R	On-Site Data	WQ Units
2.5			1.1			2.5				µg/L
2.5			1.1			2.5				µg/L
2.5			1			2.5				µg/L
2.5			0.7			2.5				µg/L
2.5			1.2			2.5				µg/L
2.5			0.7			2.5				µg/L
2.5			0.8			2.5				µg/L
2.5			0.8			2.5				µg/L
2.5			0.5			2.5				µg/L
2.5			1.3			2.5				µg/L
2.5			0.8			2.5				µg/L
2.5			1			2.5				µg/L
2.5			1			2.5				µg/L
16.7			0.7			2.5				µg/L
2.5			0.4			2.5				µg/L
2.5			0.6			2.5				µg/L
2.5			0.9			2.5				µg/L
2.5			0.9			2.5				µg/L
2.5			1.6			2.5				µg/L
2.5			0.9			2.5				µg/L
3.8			0.4			2.5				µg/L
2.5			3.1			2.5				µg/L
2.5			0.9			2.5				µg/L
2.5			1.4			2.5				µg/L
2.5			0.8			2.5				µg/L
2.5			0.4			2.5				µg/L
2.5			0.3			2.5				µg/L
2.5			0.5			2.5				µg/L
2.5			0.4			2.5				µg/L
2.5			2.5			2.5				µg/L
2.5			4.7			2.5				µg/L
2.5			1.5			2.5				µg/L
2.5			1.4			2.5				µg/L
2.5			0.8			2.5				µg/L
2.5			1			2.5				µg/L
2.5			1			2.5				µg/L
2.5			0.7			2.5				µg/L

Total As

Denver Wastewater Building	I-5/SR-78 P&R	La Costa P&R	Lakeview 2	Lakeview 4	Lakewood P&R	Lakeview Shops	Termination P&R	Via Verde P&R	On-Site Data	WQ Units
2.5			0.7			2.5				µg/L
2.5			0.4			2.5				µg/L
13.9			1.9			2.5				µg/L
2.5			0.6			2.5				µg/L
14.9			0.6			2.5				µg/L
2.5			0.9			2.5				µg/L
2.5			0.7			2.5				µg/L
2.5			0.6			2.5				µg/L
12.2			0.4			2.5				µg/L
0.5			0.7			2.5				µg/L
1.6			0.3			2.5				µg/L
0.5			0.6			2.5				µg/L
2.2						2.5				µg/L
10.9						2.5				µg/L
1.1						2.5				µg/L
7.9						2.5				µg/L
2.4						2.5				µg/L
10.1						2.5				µg/L
5.5						2.5				µg/L

Dissolved As

I-5/SR-78 P&R	La Costa P&R	Lakewood P&R	Termination P&R	Via Verde P&R	On-Site Data	WQ Units
0.88	0.5	1	0.5	0.5	0.38108387	µg/L
0.8	1	0.5	0.5	0.5	0.25844813	µg/L
2.4	1.2	0.5	0.5	0.5	0.19228095	µg/L
2.4	0.55	1	0.7	0.5	0.24841099	µg/L
0.5	0.5	0.7	0.5	0.5	0.21378333	µg/L
0.68	2.2	3.9		0.5	0.1826087	µg/L
1.3	1.5			0.6	0.2	µg/L
1.1	1			0.5	0.24792208	µg/L

1.5	0.5				0.34293216	µg/L
0.5					0.30632417	µg/L
1.7						µg/L

Total Cd

	Medium Density Residential	Roads/Highway	Office Commercial	Low Density Commercial	Office Commercial	Office Commercial	Office Commercial	Office Commercial	Office Commercial	Roads/Highway	Roads/Highway	Maintenance Station	Roads/Highway	Roads/Highway	Roads/Highway	Roads/Highway	Roads/Highway	Roads/Highway	Roads/Highway
On-Site Data	Iris Rain Garden	Cottonwood RVTS	Elm Drive	Grant Ranch	IX-2	IX-3	IX-4	IX-5	IX-7	Moreno A RVTS	Moreno B RVTS	Mount Shasha	Mountain Gate Sand Filter	Murrieta RVTS	Redding RVTS	Sacramento RVTS	San Onofre RVTS	San Rafael RVTS	Yorba Linda RVST
0.078	0.5	0.82	0.09	0.5	2.5	2.5	0.22	1	1	0.83	0.25	0.1	0.4	0.31	0.1	0.47	0.2	1.7	0.97
0.367	0.5	2.9	0.16	0.5	2.5	0.5	0.53	0.5	0.5	0.4	0.21	0.04	1.1	0.14	0.1	0.1	0.99	1	0.86
0.458	0.5	0.59	0.09	0.5	0.5	0.25	0.2	0.25	0.25	0.4	0.34	0.1	0.44	0.005	0.1	0.1	1.2	0.8	0.4
0.332	0.5	0.63	0.05	0.5	0.5	0.23	0.2	0.3	0.3	0.3	0.005	0.1	0.37	0.38	0.31	0.45	1.1	0.48	1.3
0.122	0.5	0.64	0.1	0.5	0.3	0.24	0.07	0.2	0.2	0.3	0.12	0.1	0.27	0.18	0.1	0.5	1.4	0.41	1.3
0.233	0.5	0.73	0.08	0.1	0.12	0.19	0.08	0.2	0.2	0.1	0.21	0.1	0.38	0.13	0.1	0.1	1.6	0.69	0.8
0.193	0.5	1.2	0.1	0.1	0.13	0.2	0.09	0.35	0.35	0.2	0.005	0.1	0.04	0.19	0.24	0.1	0.7	0.35	3

0.032	0.5	0.58	0.15	0.1	0.19	0.29	0.14	0.15	0.15	0.4	0.28	0.1	0.6	0.16	0.1	0.38	1.8	0.42	0.3
0.723	0.5	0.5	0.09	0.1	0.33	0.16	0.1	0.25	0.25	0.65	0.23	0.05	0.1	0.07	0.1	0.1	0.7	0.59	1
0.165	0.5	0.45	0.06	0.1	0.18	0.09	0.21	0.14	0.14	0.45	0.22	0.04	0.1	0.005	0.5	0.64	0.7	0.36	0.7
	0.3	0.96	0.09	0.2	0.08	0.17	0.19	0.09	0.09	0.4	0.12	0.05	0.4	0.22	0.1	0.42	0.2	0.63	0.7
	0.6	1.3	0.12	0.5	0.16	0.13	0.16	0.05	0.05	0.69	0.22	0.04	0.46	0.08	1.2	1.6	1.4	0.4	1.3
	0.2	0.1	0.25	0.5	0.1	0.15	0.24	0.3	0.3	1.1	0.005	0.05	0.33	0.005	0.87	0.48	1.2	0.2	0.6
	0.1	0.2	0.1	0.5	0.23	0.11	0.11	0.25	0.25	0.1	0.16	0.05	0.28	0.23	0.42	0.71	1.2	0.63	0.6
	0.3	0.5	0.09	0.5	0.14	0.12	0.5	0.25	0.25	0.3	0.29	0.05	0.48	0.11	0.97	0.57	0.94	1	0.67
	1	0.8	0.1	0.5	0.18	0.2	0.25	0.17	0.17	0.4		0.05	5.1	0.005	0.54	0.5	0.81	0.29	0.5
	0.2	0.6	0.21	5	0.4	0.11	0.24	0.05	0.05	0.1		0.05	0.5	0.1	0.1	0.6	1.8	0.53	0.54
	0.2	1.1	0.1	0.05	0.14	0.14	0.49	0.1	0.1	0.3		0.05	0.29		0.1	0.8	1.2	0.74	0.7
	0.2	0.41	0.2	5	0.2	0.19	0.21	0.2	0.2	0.33		0.05	0.25		0.1	1.4	0.9	0.6	0.64
	0.2	0.73	0.2	5	0.09	0.12	0.15			0.34		0.05	0.195		0.2	0.4	1.2	0.2	0.8
	0.2	1	0.42	5	0.21	0.09	0.3			0.25		0.05	0.33		0.05	0.8	0.4	0.2	0.3
	0.4	0.5	0.23	5			0.11			0.4		0.05	0.13		0.8	0.2	1.3	0.6	0.6
	0.5	0.6	0.17	5			0.15			1.2		0.05	0.4		0.1	0.2	0.5	0.2	0.035
	0.2	0.1	0.11	5						0.2		0.05	0.3		0.2	0.2	0.33	0.2	0.8
	0.2	0.1	0.16	5	2.5					0.6		0.03	0.35		0.4	0.4	0.5	0.1	0.3
	0.1	0.3	0.09	5						0.2			0.73		0.2	0.1	0.2	0.2	3.5
	0.3	0.6	0.05	0.5						0.7			0.48		0.1	0.3	1.8	0.2	1.2
	0.1	0.3	0.1	0.6						0.2			0.5		0.5	0.2	0.54	0.2	0.6
	0.1	0.39	0.09	0.25						0.2			0.34		0.09	0.3	0.1	0.7	0.6
	0.2	0.1	0.09	0.25						0.5			0.1		0.2	0.2	0.2	0.3	1.3
	0.5	0.1	0.12	0.25						0.27			0.1		0.09	0.6	0.4	0.8	0.6
	0.5	0.1	0.1	0.25						0.21			0.1		0.2	0.4	0.66	0.4	1.6
	0.5	0.1	0.21	0.7						0.25			0.1		0.035	0.2	0.6	0.4	0.4

	0.5	0.1	0.2	0.25						0.66			0.1		0.4	0.85	0.5	0.2	0.7
	0.5	0.1	0.2	0.25						0.7			0.38		0.1	0.5	0.3	0.9	0.6
	0.5	0.1	0.42	0.25						0.88			0.04		0.1	1	0.2	0.1	0.37
	0.5	0.1	0.23	0.25						0.1			0.29			0.4	0.1	0.31	0.29
	0.8	0.1	0.11	0.5						0.3			0.44		0.49	0.3	0.33	0.1	0.65
	0.2	0.27	0.21	0.5						0.2			0.37		2.8	0.33	0.43	0.1	0.97
	0.2	0.1	0.19	0.25						0.3			0.25		0.1	0.1	0.24	0.2	0.44
	0.5	0.2	0.31	2.4						0.3			0.195		0.1	0.1	0.035	0.3	0.45
	0.2	0.3	0.37	0.25						0.5			0.33		0.1	0.1	0.3	0.1	1.2
	0.2	1	0.4	0.25						0.1			0.13		0.1	0.32	0.1	0.1	0.7
	0.2	0.4	0.2	0.25						0.22			0.4		0.2	0.1	0.2	0.1	1.5
	0.2	0.1	0.15	0.25						0.27			0.3		0.1	0.4	0.31	0.1	0.6
	0.4	0.3	0.1	0.25						0.75			0.48		0.1	0.1	0.89	0.1	0.6
	0.2		0.46	0.25						3.3			5.1		0.2	0.1	0.1	0.1	0.4
	0.2		0.41	0.25						0.1					5	0.1	0.6	0.1	0.2
	0.2		0.11	0.25						0.3					0.6	0.1	0.2	0.31	0.5
	0.5									0.3					0.1	0.56	0.3	0.1	0.2
	0.4									0.4					0.035	0.29	0.1	0.1	0.4
	0.1									0.2					9.4	0.1	0.1	3.7	0.43
	0.1									1.1					0.1	0.2	0.1	0.34	0.1
	0.1									0.8					0.1	0.1	0.4	0.35	0.29
	0.1									0.26					0.1	0.1	0.4	0.1	0.38
										0.28					0.1	0.43	0.33	0.1	0.41
										0.43					0.1	0.1	0.34	0.1	0.1
										0.8					0.14	0.53	0.3	0.1	0.3

Dissolved Cd

	Medium Density Residential	Highway/Roads	Low Density Residential	Roads/Highways	Roads/Highways	Maintenance Station	Roads/Highways	Roads/Highways	Roads/Highways	Roads/Highways	Roads/Highways	Roads/Highways	Roads/Highways
On-Site	21st and Iris Rain Garden	Cottonwood RVTS	Grant Range	Moreno A RVTS	Moreno B RVTS	Mount Shasta Maintenance Station	Mountain Gate Sand Filter	Murrieta RVTS	Redding RVTS	Sacramento RVTS	San Onofre RVTS	San Rafael RVTS	Yorba Linda RVTS
0.06513213	0.05	0.1	0.05	0.24	0.005	0.1	0.1	0.03	0.1	0.1	0.2	0.23	0.1
0.341318026	0.1	0.78	0.05	0.4	0.08	0.04	0.98	0.02	0.1	0.1	0.29	0.23	0.24
0.503472022	0.1	0.1	0.05	0.2	0.14	0.1	0.12	0.005	0.1	0.1	0.36	0.1	0.32
0.506198712	0.1	0.1	0.05	0.2	0.05	0.1	0.21	0.005	0.1	0.1	0.41	0.1	0.1
0.189384345	0.05	0.2	0.05	0.2	0.08	0.1	0.14	0.07	0.1	0.1	0.22	0.1	0.1
0.105655588	0.6	0.21	0.05	0.1	0.005	0.1	0.22	0.04	0.1	0.1	0.9	0.22	0.44
0.119273665	0.05	0.1	0.05	0.1	0.04	0.1	0.1	0.03	0.1	0.1	0.3	0.1	0.5
0.039545455	0.05	0.1	0.05	0.3	0.07	0.1	0.1	0.1	0.1	0.1	0.5	0.1	1
0.106566679	0.05	0.1	0.05	0.1	0.005	0.05	0.1	0.04	0.1	0.1	0.4	0.22	0.3
0.16915624	0.05	0.1	0.05	0.1	0.05	0.04	0.1	0.005	0.1	0.1	0.3	0.1	0.3
	0.1	0.1	0.05	0.22	0.09	0.04	0.27	0.08	0.76	0.1	0.1	0.3	0.4
	0.1	0.1	0.05	0.45	0.005	0.04	0.1	0.02	0.1	0.1	0.6	0.1	0.2
	0.2	0.1	0.05	0.1	0.04	0.04	0.1	0.005	0.1	0.1	0.1	0.2	0.1
	0.05	0.1	0.05	0.1	0.09	0.04	0.1	0.06	0.1	0.1	0.1	0.1	0.4
	0.05	0.2	0.05	0.1		0.04	0.1	0.08	0.1	0.1	0.1	0.21	0.2

	0.1	0.4	0.05	0.1		0.04	0.1	0.005	0.1	0.1	0.1	0.3	0.1
	0.1	0.2	5	0.1		0.04	0.1	0.03	0.1	0.3	0.1	0.1	0.1
	0.05	0.6	5	0.1		0.04	0.04		0.1	0.5	0.035	0.1	0.22
	0.05	0.19	0.05	0.1		0.04	0.084		0.2	0.1	0.09	0.33	0.57
	0.05	0.09	5	0.1		0.04	0.14		0.04	0.4	0.1	0.4	0.1
	0.05	0.4	5	0.1		0.04	0.2		0.6	0.4	0.08	0.1	0.08
	0.05	0.3	5	0.3		0.04	0.11		0.1	0.2	0.035	0.1	0.1
	0.05	0.5	5	0.1		0.04	0.18		0.2	0.1	0.1	0.2	0.035
	0.05	0.1	5	0.3		0.04	0.17		0.1	0.1	0.1	0.2	0.4
	0.05	0.1	5	0.1		0.05	0.26		0.1	0.2	0.1	0.1	0.035
	0.05	0.2	5	0.2			0.12		0.1	0.1	0.1	0.1	0.1
	0.05	0.4	0.3	0.1			0.21		0.4	0.2	0.2	0.2	0.1
	0.05	0.14	0.05	0.1			0.28		0.035	0.2	0.65	0.1	0.2
	0.05	0.12	0.5	0.1			0.24		0.1	0.1	0.25	0.4	0.1
	0.05	0.1	0.05	0.1			0.1		0.075	0.1	0.1	0.2	0.3
	0.05	0.1	0.05	0.1			0.1		0.07	0.1	0.1	0.2	0.3
	0.05	0.1	0.05	0.1			0.1		0.035	0.2	0.2	0.4	0.4
	0.05	0.1	0.3	0.1			0.1		0.2	0.1	0.1	0.2	0.1
	0.05	0.1	0.05	0.56			0.1		0.035	0.035	0.1	0.1	0.2
	0.05	0.1	0.05	0.2			0.14		0.035	0.035	0.6	0.5	0.2
	0.05	0.1	0.05	0.1			0.22		0.1	0.2	0.2	0.1	0.1
	0.05	0.1	0.05	0.1			0.04		0.26	0.035	0.2	0.1	0.1
	0.05	0.1	0.05	0.1			0.12		0.1	0.035	0.1	0.4	0.1
	0.05	0.1	0.05	0.2			0.21		1.2	0.1	0.1	0.1	0.84
	0.05	0.1	0.05	0.1			0.084		0.1	0.1	0.1	0.1	0.1
	0.05	0.1	1.2	0.1			0.14		0.1	0.1	0.035	0.2	0.1
	0.05	0.1	0.05	0.2			0.2		0.1	0.1	0.1	0.1	0.1
	0.05	0.7	0.05	0.1			0.11		0.1	0.1	0.07	0.1	0.4
	0.05	0.2	0.05	0.1			0.18		0.1	0.1	0.035	0.1	0.5

	0.05	0.1	0.05	0.1			0.17		0.1	0.2	0.1	0.1	0.2
	0.05	0.2	0.05	0.58			0.21		0.1	0.1	0.1	0.1	0.2
	0.05		0.05	0.1			0.1		0.2	0.1	0.1	0.1	0.1
	0.05		0.05	0.1					0.1	0.1	0.2	0.1	0.2
	0.05		0.05	0.1					0.1	0.1	0.2	0.1	0.2
	0.05			0.1					2.4	0.21	0.2	0.1	0.1
	0.05			0.1					0.1	0.1	0.1	0.1	0.1
	0.05			0.1					0.1	0.1	0.1	0.1	0.1
	0.05			0.1					0.1	0.1	0.1	0.2	0.1
	0.05			0.1					0.1	0.2	0.2	0.1	0.22
	0.05			0.1					0.1	0.1	0.1	0.1	0.1
	0.05			0.1					0.1	0.1	0.1	0.1	0.1
				0.22					1.6	0.1	0.1	0.1	0.1
				0.63					0.035	0.1	0.2	0.1	0.1
									0.07	0.4	0.1	0.2	0.1
									0.035	0.4	0.1	0.1	0.1
									0.035	0.4	0.1	0.1	0.1
									0.035	0.5	0.3	0.1	0.1
									0.035	0.1	0.1	0.1	0.2
									0.035	0.1	0.64	0.1	0.1
									0.035	0.2	1.6	0.2	0.1
									0.1	0.1	0.79	0.1	0.1
									0.1	0.1	0.24	0.1	0.1
									0.1	0.035		0.1	0.2
									0.1	0.035		0.1	0.1
									0.2	0.1		0.2	0.23
									0.1	0.035			0.1
									0.1	0.035			1.2
									0.1	0.1			1.9

Total Cu

On-Site Data	Iris Rain Garden	Cottonwood RVTS	Elm Drive	Grant Ranch	IX-2	IX-3	IX-4	IX-5	IX-7	Moreno A RVTS	Moreno B RVTS	Mount Shasha	Mountain Gate Sa	Murrieta RVTS	Redding RVTS	Sacramento RVTS	San Onofre RVTS	San Rafael RVTS	Yorba Linda RVST
6.46	27.8	26	8	8.7	25	25	13.4	10	25	40	31	4.8	12	22	4.9	15	18	82	37
23.08	9.6	85	8.6	7.7	25	16	9.5	5	11	100	22	0.48	6	10	1.5	12	46	55	49
14.15	12	23	5.3	23.9	17	26	6.4	20	40	43	34	3.6	13.1	11	7.3	7	54	43	89
23.14	6.2	19	4.7	4.3	6	17	6.3	13	24	21	23	2.6	11.4	24	2.4	14	61	33	60
10.88	4.9	26	3.4	6.3	13	12	10.5	2.5	14	25	16	2.8	8.8	13	3.1	20	52	30	50
0.96	13.7	33	4.8	9	13	14	9.4	11	9	16	26	13	1.8	9.7	4.5	11	76	41	100
0.80	8.9	20	5	13.3	15	5	4.1	9	20	22	23	3.3	11	16	2.7	8.4	41	22	16
2.66	13.6	20	6.7	26.7	12.6	14	11.9	9	14	34	32	7.9	2.3	18	5	7.8	87	29	31
8.39	7.2	21	5.1	5.2	13.4	15	10.2	8	29	60	28	0.77	4	7.9	3	7.4	25	44	30
3.70	5.8	19	5.2	5.2	10.8	4.2	10.2	11	17	47	22	6	13	7.3	3.2	18	35	24	21
	22.4	60	5.1	5.2	3.7	9.5	11.9	11	10	51	13	3	12	19	3.5	9.6	13	41	53
	22.4	51	5.4	10	10.7	10.8	3.3	7	12.5	110	24	3.6	13	8.4	13	26	62	54	30
	45.9	26	7	9.7	10.7	6	2.6	6	12.5	51	18	9.7	7.4	12	9.2	15	58	19	37
	20.9	19	7	1.25	11.8	3.3	11.1	5	5	25	20	4.3	22.6	20	5.4	15	57	22	47
	10.5	21	11.4	3.3	25.6	6.4	24	26	7	24	25	1.8	23	12	3.9	21	50	44	31

	30.7	33	14.7	4.5	16	6	16	8.6	4.4	27		3	9.4	5	2.2	5.7	46	81	40
	53.6	26	8.8	7.78	7.6	5.5	14	5	8	20		8.7	6.8	8.3	4.9	13	99	22	33.5
	12	53	7.3	11.7	11.6	5.6	11	3	5	29		1.4	7.6		6	3.3	75	43	60
	11.8	27	13.3	12	3.9	8.9	6.4	7		36		4.2	15.3		3.3	13	57	50	41
	9.2	35	6.9	17.4	11	11.1	7			38		1.2	7.45		8.2	21	78	40	25
	23.3	56	16.8	30.6	14.8	8.7	18.9			28		5.1	8.7		8.5	15	40	17	31
	33	27	11.5	9.05			4.7			77		61.6	3.4		26	19	74	24	73
	5.1	48	6.7	15.6			6.4			48		8.5	15.7		4	8.2	40	51	12
	5.1	6	5.6	8.44						71		4	8.3		5.6	13	47	34	130
	29.8	7.1	8.6	11.1						51		4.2	6.5		10	8.5	35	4.7	10
	10.7	22	5.3	5.77						21			19.2		1.95	6.1	26	15	56
	17	12	4.7	5.1						37			12.9		9	21	32	32	42
	8	6.8	3.4	34.1						14			10.8		3.2	13	49	34	25
	20.1	7.3	5.1	7						17			13.2		3.2	19	8.8	90	31
	11.2	5.1	5.1	4.1						38			12		1.2	14	18	47	52
	31	5.9	5.4	7.5						31			5.4		4.3	37	26	110	53
	23.2	6.8	14.7	12.2						23			3.1		3	26	39	60	85
	14.2	4	8.8	23.3						38			7.2		2.5	15	75	70	26
	24.6	4.2	13.3	5.5						70			5.2		2.7	43	42	23	28
	16.5	3.7	6.9	5.4						39			8.8		4.5	24	25	130	41
	14.8	4.5	16.8	5.5						18			1.8		3.8	27	10	9.4	31
	48.9	2.8	11.5	21.3						42			7.6		3.3	24	18	5.4	20
	27.5	9.1	5.6	11.6						53			13.1		18	22	23	20	46
	10.9	7.6	12	8.6						33			11.4		1.5	13	27	5.9	47
	30	11	13	15.9						22			15.3		3.2	4.7	30	5.3	48
	9.3	12	18	10.6						25			7.45		1.8	6	27	3.4	52
	18.2	9.4	12	12.4						27			8.7		2	8.9	30	13	38

	20.3	12	18.6	9.6						18			3.4		4.3	1.9	19	6.5	47
	19.3	6.4	9.7	4.3						20			15.7		5.8	10	12	4.8	77
	30.4	20	7.2	10.4						21			8.3		3.4	21	19	3.6	33
	16.8	7.5	18	6.6						45			10.8		2.7	3.5	41	5	15
	9.9		10.3	8.5						67			23		4.9	5.6	44	5.4	17
	4.4		10.5	21.5						49					9.8	2.9	46	9.2	9.4
	28.1		7.5	16.7						38					4.5	5	20	16	27
	26.4									22					11	13	18	4.6	15
	11									32					4.4	5.9	18	9.7	28
	9.6									21					2.3	14	10	8.5	28
	14.4									43					2.3	12	13	3.6	12
	7.4									48					2.5	13	28	1.4	32
	44.8									25					2.9	12	24	4.4	43
										23					4.2	4.6	20	6.4	45
										24					4.3	9.6	26	12	9.6
										51					5.1	7.6	23	7.9	23
															4.8	19	26	9.4	21
															2.4	11	22	6.1	26
															4.6	13	11	4.9	16
															3.2	16	18	5.3	17
															1.9	9.6	7.5	8.6	7.1
															1.7	8.3	29	6	8.8
															4.6	20	13	11	15
															3.6	33	20	10	14
															2.7	12	35	7.8	7.9
															2.3	22		6.3	6.6
															1.2	16		8.4	13
															0.5	18.5		55	12
															3	17			8.5

															4.2	13			26
															3.5	4.1			29
															1.3	7.3			28
															1.3	11			37
															2	4.4			15
															1.3	5.9			17
															1.1	2.4			9.6
															2.6	6.2			31
															3	8.3			43
															4.4	3.9			
															0.5	3			
															4.9	5.1			
															1.2	7.7			
															4.8	4.8			
															8.1	5.9			
															2.3	5.8			
															7.4	13			
															90	12			
															5.25	4.6			
															2.5	14			
															6.4	9.2			
															2.7	12			
															1.9	25			
															1.5	21			
															3	8.9			
															2.3	7.7			
															3.4	3.8			
															1.9	6			
															2.2	7.3			

Dissolved Cu

On-Site Data	Medium Density Residential 21st and Iris Rain Garden	Roads/Highway Cottonwood RVTS	Low Density Commercial Grant Ranch	Roads/Highway Moreno A RVTS	Roads/Highway Moreno B RVTS	Maintenance Station Mount Shasta Maintenance Station Influent	Roads/Highway Mount Gate Sand Filter Influents	Roads/Highway Murrieta RVTS	Roads/Highway Redding RVTS	Roads/Highway Sancramento RVTS	Roads/Highway San Onofre RVTS	Roads/Highway San Rafael RVTS	Roads/Highway Yorba Linda RVTS
6.74	9.7	7.8	3.1	20	28	2.5	4.1	8.4	1.5	11	14	18	9.7
7.70	5.7	33	1	87	17	2.1	1.2	5.9	1.4	1.8	19	20	37
16.52	4.1	9.2	8	28	31	1.1	1.2	5.7	1.2	3.2	37	8	58
24.08	2.8	5.1	3.7	15	20	0.5	3.1	12	0.5	13	29	13	10
1.87	7.5	8.4	4	15	13	7.3	4	8.1	1.2	8.6	14	17	23
0.83	12.5	12	7.1	11	26	1	4.1	5.1	1.2	1.5	46	13	37
0.57	5.7	4	4.1	15	18	2	6.5	12	1.4	2.5	17	9.3	38
3.05	8.4	4	6	19	11	0.62	2.2	18	0.5	2.5	23	13	15
5.39	3.2	5.7	4.1	27	31	0.44	1.2	6.8	2.5	3.6	17	21	12
3.76	3.1	4.7	2.8	20	16	1.2	1.9	7.4	1.3	2.4	22	12	22
	5	6.2	3.7	41	11	0.95	7.2	14	2.5	4.7	8.5	13	7.6
	4.8	18	5.2	99	28	3.5	7.8	5.7	3.2	5.8	28	41	6.2
	4.8	13	3.5	21	21	7.1	6.5	8.9	0.5	5.3	15	18	14
	6.8	16	2.2	24	11	1.1	2	16	0.5	3.8	14	20	15
	8.7	11	3	15	21	0.55	1.8	12	2.2	4.3	25	18	18
	17.4	16	1	15		0.56	7.1	5.5	3	1.4	19	26	11
	11.2	9.8	13.6	12		0.67	3.9	14	3	1.6	27	9.5	25
	5.4	17	5.86	14		0.2	3		2.5	1.8	14	17	25.5

Dissolved Cu

On-Site Data	Medium Density Residential 21st and Iris Rain Garden	Roads/Highway Cottonwood RVTS	Low Density Commercial Grant Ranch	Roads/Highway Moreno A RVTS	Roads/Highway Moreno B RVTS	Maintenance Station Mount Shasta Maintenance Station Influent	Roads/Highway Mount Gate Sand Filter Influents	Roads/Highway Murrieta RVTS	Roads/Highway Redding RVTS	Roads/Highway Sancramento RVTS	Roads/Highway San Onofre RVTS	Roads/Highway San Rafael RVTS	Roads/Highway Yorba Linda RVTS
	4	16	13	20		0.2	3.6		8.2	8.4	16	23	17
	8.1	7.3	20	15		0.2	4.3		3.6	6.1	16	26	11
	2.5	45	40	25		1	2.6		21	5.9	16	11	8
	2.3	14	19.7	74		0.2	0.2		3.4	8.1	12	13	22
	3.4	36	15.5	20		0.89	4.5		5.2	6.8	34	20	8.7
	3.3	4.7	14.6	21		0.2	2.7		6.3	12	34	29	86
	3.8	4.6	5.87	62		0.73	3.1		0.7	5.8	38	4	6.2
	4.8	11	14.6	25			3.75		7.4	5.4	12	10	6.4
	4.4	9.6	3.1	16			2.3		3.1	14	10	27	10
	3.9	5.2	29.2	14			5.1		2.2	11	21	29	11
	2.7	4.2	4.7	14			1.8		0.9	4.2	26	52	9.7
	6.3	3.5	2.6	14			6.8		3.05	5.3	7.4	32	13
	3.8	4.6	3.6	25			1.7		1.7	12	12	37	26
	2.5	4.3	2.6	14			1.4		1.1	13	18	59	31
	4.2	2.8	9.5	37			4		0.9	12	12	34	14
	5.8	2	2.4	71			3.4		2.8	8	58	17	9.5
	3.1	1.8	4.3	16			4.1		1.3	5	21	91	15
	7.4	2	4.2	20			6.5		1.2	5	21	7	14
	3.4	1.5	7.6	40			1.2		0.5	6	9.6	2.8	7.7

Dissolved Cu

On-Site Data	Medium Density Residential 21st and Iris Rain Garden	Roads/Highway Cottonwood RVTS	Low Density Commercial Grant Ranch	Roads/Highway Moreno A RVTS	Roads/Highway Moreno B RVTS	Maintenance Station Mount Shasta Maintenance Station Influent	Roads/Highway Mount Gate Sand Filter Influents	Roads/Highway Murrieta RVTS	Roads/Highway Redding RVTS	Roads/Highway Sancramento RVTS	Roads/Highway San Onofre RVTS	Roads/Highway San Rafael RVTS	Roads/Highway Yorba Linda RVTS
	10.2	5	5.1	22			3.1		1.9	6	16	3.3	21
	4.8	7.5	10.3	14			4		2.3	5.7	19	11	43
	7.6	5.6	6.2	10			3.6		1.1	2.6	11	5.6	29
	6.6	9	7.3	14			4.3		1.4	3.2	19	4.7	35
	4.3	6.2	6.4	15			2.6		0.5	0.5	18	2.7	11
	3.4	6.7	4.6	16			0.2		0.5	4.2	13	2.3	47
	5	4.5	3.9	12			4.5		2.7	14	6.5	2.6	36
	6.9	15	5.7	29			2.7		4.1	1.5	9.6	2	19
	6	6.6	5.7	44			2.3		0.5	2.6	13	3.4	8
	3.1		8.1	13			7.1		6.6	1.9	39	3.8	9.2
	4.2		7	39					3.6	2.6	19	3.1	6.3
	2.8		10.1	18					4.7	5.6	17	2.7	14
	4.6			22					0.5	3.3	14	4.7	9.9
	5.8			14					2.2	3.6	17	2.3	14
	3.4			11					2.3	5.7	8.3	2.8	11
	5.2			10					2.4	10	12	0.5	6.6
	4.6			13					2.4	5.8	18	4.4	32
	5.3			19					3.2	7.7	16	6.3	30
	6.2			13					2.5	3.1	10	7.8	51

Dissolved Cu

	Medium Density Residential	Roads/Highway	Low Density Commercial	Roads/Highway	Roads/Highway	Maintenance Station	Roads/Highway	Roads/Highway	Roads/Highway	Roads/Highway	Roads/Highway	Roads/Highway	Roads/Highway
On-Site Data	21st and Iris Rain Garden	Cottonwood RVTS	Grant Ranch	Moreno A RVTS	Moreno B RVTS	Mount Shasta Maintenance Station Influent	Mount Gate Sand Filter Influents	Murrieta RVTS	Redding RVTS	Sancramento RVTS	San Onofre RVTS	San Rafael RVTS	Yorba Linda RVTS
				21					3.8	2.3	21	7	5.4
				49					2.1	4.4	18	9.2	21
									4.4	9.3	14	5.4	10
									2.9	9.1	16	4.8	11
									1.3	5.9	9.8	4.8	14
									1.2	10	11	7.3	8.9
									3.6	8.2	5.5	5.9	5.6
									2	5.6	13	18	6.4
									2.4	14	8.5	8.6	9.5
									1.4	17	17	9.3	8
									0.5	11	29	7.5	5.2
									2.8	14		5	6.2
									4.1	9		6.6	8.3
									3.5	11.5		29	10
									3.7	8			5.1
									0.5	10			25
									0.5	2.6			28
									0.5	5.5			12
									1.1	14			28

Dissolved Cu

On-Site Data	Medium Density Residential 21st and Iris Rain Garden	Roads/Highway Cottonwood RVTS	Low Density Commercial Grant Ranch	Roads/Highway Moreno A RVTS	Roads/Highway Moreno B RVTS	Maintenance Station Mount Shasta Maintenance Station Influent	Roads/Highway Mount Gate Sand Filter Influents	Roads/Highway Murrieta RVTS	Roads/Highway Redding RVTS	Roads/Highway Sancramento RVTS	Roads/Highway San Onofre RVTS	Roads/Highway San Rafael RVTS	Roads/Highway Yorba Linda RVTS
									0.5	10			8.3
									0.5	3.2			11
									2	3.6			7.2
									1.5	1.5			22
									2.9	4.1			14
									0.5	5			
									1.7	2.5			
									1.1	1.7			
									2.6	2.4			
									1.3	4.6			
									6.1	3.5			
									2.4	1.6			
									4.7	0.5			
									2.5	11			
									6.1	8.9			
									2.5	4.5			
									1.7	5.2			
									0.9	6.8			
									2.7	12			

Dissolved Cu

On-Site Data	Medium Density Residential 21st and Iris Rain Garden	Roads/Highway Cottonwood RVTS	Low Density Commercial Grant Ranch	Roads/Highway Moreno A RVTS	Roads/Highway Moreno B RVTS	Maintenance Station Mount Shasta Maintenance Station Influent	Roads/Highway Mount Gate Sand Filter Influents	Roads/Highway Murrieta RVTS	Roads/Highway Redding RVTS	Roads/Highway Sancramento RVTS	Roads/Highway San Onofre RVTS	Roads/Highway San Rafael RVTS	Roads/Highway Yorba Linda RVTS
									1.7	13			
									2.9	7.9			
									2.7	3.7			
									1.9	2.1			
									2.6	3.4			
									3.8	5.3			
									0.5	4.5			
									1.3	1.6			
									1.2	1.7			
									2.1	1.4			
									6.2	4.9			

Total Pb

On-site	Medium Density Residential Iris Rain Garden inlet	Roads/Highway Cottonwood RVTS	Office Commercial Elm Drive	Low Density Commercial Grant Ranch	Office Commercial IX-2	Office Commercial IX-3	Office Commercial IX-4	Office Commercial IX-5	Office Commercial IX-7	Roads/Highway Moreno A RVTS	Roads/Highway Moreno B RVTS	Maintenance Station Mount Shasha	Roads/Highway Mountain Gate	Roads/Highway Murrieta RVTS	Roads/Highway Redding RVTS	Roads/Highway Sacramento RVTS	Roads/Highway San Onofre RVTS	Roads/Highway San Rafael RVTS	Roads/Highway Yorba Linda RVST
1.65	19	54	0.92	2.5	12.5	12.5	12.4	5	12.5	13	2.7	0.5	2.6	9.1	2.9	6.6	15	26	22
6.17	2.5	6.5	6.13	2.5	12.5	18	3.37	6	5.7	12	3.9	1.7	6.8	4.3	0.5	4.3	30	45	25
3.49	5.7	7.1	1.9	6.1	2.5	18	2.59	9.7	12	10	6.2	0.5	3.7	2.9	1.2	3	44	22	40
4.17	2.5	5.6	1.24	2.5	6.3	18	2.58	6.8	8	5.4	3.2	0.5	2.8	10	6.6	5.3	39	23	34
4.43	2.5	5.8	0.94	2.5	8.6	14	4.48	4.9	25.5	8	2.8	1	3.4	3.1	1.5	0.5	79	16	25
1.24	6.1	6	1.4	1.7	35	14	4.78	3	13.6	3.8	4.8	3.3	4.5	3.9	1.8	1.6	110	8.6	45
0.61	2.5	7.4	0.42	4.5	19	6.3	5.24	2.48	9.8	5.9	3.4	1.1	0.5	4.5	3.1	2.7	39	17	4
3.19	2.5	4.7	0.66	3.8	17.2	6.2	4.94	4.4	6.6	8.9	7.8	3.4	2.3	1.3	1.8	1.9	57	0.5	23
14.51	2.5	4.6	0.3	0.5	52.1	6.62	5.5	2.51	8.7	16	5	0.3	2.8	1.5	1.7	6.1	39	9.6	18
91.66	2.5	5.6	0.31	1.6	14.6	6.04	4.64	3.5	7.4	11	3.2	0.06	0.5	0.03	3.3	2.8	54	11	12
	16	14	0.5	1	8.38	4.9	4.46	3.8	11	5.5	2.5	0.61	0.5	4.7	2.1	8.4	20	5.7	31
	30.3	4.1	1.4	2.5	12.8	8.21	2.7	3	8.3	9	3.9	0.83	0.5	2.4	13	5	190	4.5	14
	8.1	25	1.25	2.5	6.4	4.61	4.16	6	20.5	32	3.4	1.3	13.7	2.8	7.5	6.7	190	14	17
	6.9	6	1	2.5	27.6	6.25	2.51	4.1	6.4	3.7	3.6	0.92	14	4.8	2.5	8.8	130	3.2	34

Total Pb

	Medium Density Residential	Roads/Highway	Office Commercial	Low Density Commercial	Office Commercial	Office Commercial	Office Commercial	Office Commercial	Office Commercial	Roads/Highway	Roads/Highway	Maintenance Station	Roads/Highway	Roads/Highway	Roads/Highway	Roads/Highway	Roads/Highway	Roads/Highway	Roads/Highway
On-site	Iris Rain Garden inlet	Cottonwood RVTS	Elm Drive	Grant Ranch	IX-2	IX-3	IX-4	IX-5	IX-7	Moreno A RVTS	Moreno B RVTS	Mount Shasha	Mountain Gate	Murrieta RVTS	Redding RVTS	Sacramento RVTS	San Onofre RVTS	San Rafael RVTS	Yorba Linda RVST
	6	8.1	1.36	2.5	7.51	3.95	24	7.9	7.4	7.6	5.3	0.58	3.1	1.8	7.5	3.2	120	21	32
	40.6	7.8	1.82	2.5	24	12.5	18.2	3.7	5.36	13		0.35	1.4	0.03	0.5	6.2	63	31	25
	4.9	12	1.57	36.5	10.5	10.8	10.3	2.7	7.4	7.2		1.2	0.06	2	2.4	0.5	240	7.8	14
	8.3	3.5	1.4	36.5	7.29	6.1	13	2.5	6.9	14		0.39	3.5		2.7	3.3	120	15	30
	3.2	6.9	1.5	0.05	3.19	4.45	6.89	2.38		8.6		1.1	3.8		1.2	7.2	130	16	17
	2.4	9.4	6.1	36.5	13.1	13	4.3			9.8		0.42	1.2		3.3	4.7	120	14	0.8
	4.8	4.2	17.9	36.5	7.73	6.01	9.61			1.4		0.86	2.1		1.3	4.4	50	6.3	12
	19.2	6	1.2	36.5			4.7			5.1		1.2	0.67		2.2	1.9	190	8.6	28
	21.5	2.6	2.09	36.5			4.91			42		2	4.3		0.5	0.5	39	21	0.7
	1	1.6	0.8	36.5						6.2		0.89	2.5		1	0.5	20	2.8	31
	1	6.1	6.13	36.5						23		0.52	1.8		2.4	1.5	74	0.5	4.9
	3.7	5.3	1.9	36.5						7			6.4		1.2	0.5	28	2.8	95
	4.4	0.5	1.24	5						22			3.25		0.5	4.2	23	3.5	40
	13.8	1.8	0.94	2.5						5.4			3.2		0.5	3.1	53	4.5	25
	6.2	1.2	0.3	2.5						6.1			2		0.4	4.7	13	16	35
	11.1	2	0.5	2.5						18			0.5		0.2	3.1	42	5.2	47
	5.6	1.7	1.4	2.5						4.5			0.5		9.05	7.3	100	33	17
	24.3	2.7	1.82	5.3						4.5			0.5		0.6	4.4	52	11	22
	20	1.1	1.57	6.6						3.7			2.6		0.6	1.6	37	10	37

Total Pb

On-site	Medium Density Residential Iris Rain Garden inlet	Roads/Highway Cottonwood RVTS	Office Commercial Elm Drive	Low Density Commercial Grant Ranch	Office Commercial IX-2	Office Commercial IX-3	Office Commercial IX-4	Office Commercial IX-5	Office Commercial IX-7	Roads/Highway Moreno A RVTS	Roads/Highway Moreno B RVTS	Maintenance Station Mount Shasha	Roads/Highway Mountain Gate	Roads/Highway Murrieta RVTS	Roads/Highway Redding RVTS	Roads/Highway Sacramento RVTS	Roads/Highway San Onofre RVTS	Roads/Highway San Rafael RVTS	Roads/Highway Yorba Linda RVST
	6.9	1.5	1.5	2.5						4.1			0.5		0.9	10	21	3.3	18
	27.1	2	6.1	2.5						31			3.4		0.8	6	12	15	22
	7.1	2.2	17.9	2.5						29			0.06		1.35	7	13	1.7	15
	9.5	1.5	1.2	2.5						9.5			3.5		9.5	6	7.8	2.2	15
	30.3	2.1	0.8	5						14			6.8		5.6	5	43	1	30
	19	1.6	2.2	5						6.4			3.7		2.4	4.5	43	2.1	4.6
	2	3.4	2.23	2.5						12			3.8		42	1.2	14	1.1	27
	18.9	9.5	6.91	2.5						13			1.2		1.5	1.6	24	0.5	28
	4.5	1.2	1.6	2.5						14			2.1		6.1	2.6	48	0.5	55
	12	2.9	5.2	2.5						2.6			0.67		4	0.5	13	2.1	34
	10.7	1	2.61	2.5						2.9			4.3		13	0.5	15	1.1	47
	8.7	5.3	1.38	2.5						1.2			2.5		0.5	3.5	34	1.5	19
	21.7	0.5	5.3	2.5						2.6			3.2		8.9	1.3	110	1.6	16
	9.5		4.34	5.2						46			14		0.5	0.5	30	1.1	14
	4		4.2	2.5						5.7					1.6	2.8	80	3.6	8.1
	1		2.31	2.5						20					0.5	0.5	22	11	14
	22.9									13					7.9	3.9	31	1.8	9.8
	17.6									26					0.5	1.5	16	3.4	20
	6.4									13					0.5	1.9	12	9.8	20

Total Pb

	Medium Density Residential	Roads/ Highway	Office Commercial	Low Density Commercial	Office Commercial	Office Commercial	Office Commercial	Office Commercial	Office Commercial	Roads/ Highway	Roads/ Highway	Maintenance Station	Roads/ Highway	Roads/ Highway	Roads/ Highway	Roads/ Highway	Roads/ Highway	Roads/ Highway	Roads/ Highway
On-site	Iris Rain Garden inlet	Cottonwood RVTS	Elm Drive	Grant Ranch	IX-2	IX-3	IX-4	IX-5	IX-7	Moreno A RVTS	Moreno B RVTS	Mount Shasha	Mountain Gate	Murrieta RVTS	Redding RVTS	Sacramento RVTS	San Onofre RVTS	San Rafael RVTS	Yorba Linda RVST
	4									52					0.5	2.2	11	2.2	9.1
	4.7									43					0.5	1.7	59	0.5	5.1
	1.6									6.4					0.5	3.8	50	1	26
	25.3									5.1					0.5	1.1	27	1.5	17
										3.6					0.6	4.6	28	2.7	8.2
										5.3					1	0.5	41	1.6	42
															0.4	6	62	0.5	34
															0.2	1.9	75	0.5	11
															0.3	1.9	14	1	14
															0.4	2.7	51	0.5	6.8
															0.6	0.5	3.4	0.5	6.8
															0.4	0.5	46	0.5	8.5
															1.3	5.4	8.7	1.2	8.9
															1.7	5.3	15	0.5	17
															1.1	1.4	11	0.5	3.4
															0.5	2		0.5	4.1
															1.5	2		0.5	4.5
															0.5	4		9.4	7.1
															0.5	4			4

Dissolved Pb

On-Site	Medium Density Residential Iris Rain Garden inlet	Roads/Highway Cottonwood RVTS	Low Density Commercial Grant Ranch	Roads/Highway Moreno A RVTS	Roads/Highway Moreno B RVTS	Maintenance Station Mount Shasta	Roads/Highway Mount Gate Sand Filter Influents	Roads/Highway Murrieta RVTS	Roads/Highway Redding RVTS	Roads/Highway Sancramento RVTS	Roads/Highway San Onofre RVTS	Roads/Highway San Rafael RVTS	Roads/Highway Yorba Linda RVTS
2.60	0.5	0.5	0.5	5.5	0.03	0.5	0.5	0.11	0.5	0.5	2.6	0.5	0.5
1.19	0.5	0.5	0.5	0.5	0.11	0.06	0.06	0.03	0.5	0.5	2.6	0.5	0.5
2.14	0.5	0.5	0.5	2.6	0.16	0.5	0.06	0.03	0.5	0.5	3.4	0.5	0.5
1.86	0.5	0.5	0.5	2.6	0.03	0.5	0.06	0.07	0.5	0.5	2.7	0.5	0.5
1.30	0.5	0.5	0.5	2.7	0.07	0.5	0.5	0.09	0.5	2.6	47	0.5	2.1
1.27	0.5	0.5	0.5	1.1	0.1	0.5	0.2	0.08	0.5	0.5	15	0.5	11
0.52	0.5	0.5	0.5	2.5	0.03	0.5	2.8	0.11	0.5	0.5	9.1	0.5	12
1.93	0.5	0.5	0.5	2.4	0.03	0.5	0.5	0.14	0.5	0.5	25	0.5	2.8
10.18	0.5	0.5	0.5	0.5	0.09	0.075	0.5	0.08	0.5	0.5	29	0.5	6.6
60.30	0.5	2.8	0.5	0.5	0.03	0.06	0.5	0.03	0.5	0.5	12	0.5	10
	1	0.5	0.5	0.5	0.06	0.06	0.5	0.2	0.5	0.5	10	0.5	3.8
	1	1.4	0.5	0.5	0.11	0.06	0.5	0.12	0.5	0.5	75	0.5	1.2
	0.5	1.1	0.5	0.5	0.03	0.06	0.5	0.03	0.5	0.5	0.5	3.1	5.4
	0.5	1.8	0.5	2.3	0.03	0.06	0.5	0.12	0.5	0.5	0.5	8.5	5.1

Dissolved Pb

On-Site	Medium Density Residential Iris Rain Garden inlet	Roads/Highway Cottonwood RVTS	Low Density Commercial Grant Ranch	Roads/Highway Moreno A RVTS	Roads/Highway Moreno B RVTS	Maintenance Station Mount Shasta	Roads/Highway Mount Gate Sand Filter Influents	Roads/Highway Murrieta RVTS	Roads/Highway Redding RVTS	Roads/Highway Sancramento RVTS	Roads/Highway San Onofre RVTS	Roads/Highway San Rafael RVTS	Roads/Highway Yorba Linda RVTS
	0.5	3.6	0.5	1.8	0.1	0.06	0.5	0.37	0.5	0.5	0.5	2.8	0.5
	0.5	1.3	0.5	2.4		0.06	0.5	0.03	0.5	0.5	0.5	2.1	0.5
	0.5	1	36.5	1.7		0.06	0.5	0.21	1.3	0.5	0.5	0.5	0.5
	0.5	0.14	36.5	2		0.06	0.5		0.5	1.4	0.2	2.1	0.5
	0.5	0.12	0.05	0.5		0.06	0.06		1.1	0.5	0.5	0.5	0.2
	0.5	2.9	36.5	0.5		0.06	0.06		0.06	0.5	11	0.5	0.2
	0.5	2.6	36.5	0.5		0.06	0.06		0.5	0.5	0.4	5.8	0.1
	0.5	2.9	36.5	0.5		0.06	0.06		0.5	1.2	6.3	2.7	0.2
	0.5	0.5	36.5	0.5		0.06	0.06		0.5	0.5	1.3	1.6	0.035
	0.5	0.5	36.5	3.1		0.06	0.06		0.5	0.5	1.6	1.9	0.8
	0.5	0.5	36.5	3.3		0.25	0.06		0.5	1	2.2	0.5	0.1
	0.5	0.5	36.5	2.5			0.06		0.5	2.7	1.9	2.2	0.5
	0.5	1.2	0.5	3.4			0.06		0.5	2.1	26	2.8	0.5
	0.5	0.06	0.5	3.2			0.06		0.07	0.5	1.4	3.2	5.5
	0.5	0.1	0.5	3.4			0.06		0.08	0.5	8.1	1.4	7.5
	0.5	0.5	0.5	3.9			0.5		0.4	1.3	7	0.5	4.9
	0.5	0.5	0.5	0.5			0.5		0.035	1.1	19	5.7	3.9
	0.5	0.5	0.5	0.5			0.5		0.1	0.5	0.5	11	9
	0.5	0.5	0.5	0.5			0.5		0.035	1.75	4.2	2.1	2.2
	0.5	0.5	0.5	1.3			0.5		0.035	0.1	21	1.8	3.1

Dissolved Pb

	Medium Density Residential	Roads/Highway	Low Density Commercial	Roads/Highway	Roads/Highway	Maintenance Station	Roads/Highway	Roads/Highway	Roads/Highway	Roads/Highway	Roads/Highway	Roads/Highway	Roads/Highway
On-Site	Iris Rain Garden inlet	Cottonwood RVTS	Grant Ranch	Moreno A RVTS	Moreno B RVTS	Mount Shasta	Mount Gate Sand Filter Influents	Murrieta RVTS	Redding RVTS	Sancramento RVTS	San Onofre RVTS	San Rafael RVTS	Yorba Linda RVTS
	0.5	0.5	0.5	0.5			0.2		0.065	0.08	11	3.5	4.4
	0.5	0.5	0.5	5.8			2.8		0.5	0.035	5.9	0.5	0.5
	0.5	0.5	0.5	2.7			0.06		0.5	1	10	0.5	0.5
	0.5	0.5	0.5	3.5			0.06		0.5	0.5	8.2	0.5	0.5
	0.25	1.5	0.5	3.4			0.06		0.5	0.5	5	0.5	1
	0.25	1.4	0.5	3.4			0.06		0.5	0.5	0.5	0.5	1.8
	0.25	3.1	0.5	3.6			0.06		0.5	0.5	1.5	0.5	0.5
	0.25	0.5	0.5	4			0.06		0.5	0.5	4.1	0.5	0.5
	0.25	0.5	0.5	0.5			0.06		0.5	0.5	1.2	0.5	11
	0.25	0.5	0.5	0.5			0.06		0.5	2.6	0.5	0.5	8.2
	0.25	4.3	0.5	0.5			0.06		0.5	0.5	2.5	0.5	3.7
	0.25	0.5	0.5	0.5			0.06		0.5	0.5	4.1	0.5	4.8
	0.25		0.5	0.5			0.5		0.5	0.5	14	0.5	3.8
	0.25		0.5	1.5					0.2	0.5	17	0.5	3.3
	0.25		0.5	1.6					0.5	0.5	9.3	0.5	1.7
	0.25			6.3					0.5	0.5	18	0.5	3.4
	0.25			3.6					0.5	0.5	9	0.5	4.1
	0.25			2.6					0.5	0.5	7.5	0.5	0.5
	0.25			3.9					0.5	0.5	7.6	0.5	0.5
	0.25			3.3					0.5	0.5	24	0.5	1.2

Dissolved Pb

On-Site	Medium Density Residential Iris Rain Garden inlet	Roads/Highway Cottonwood RVTS	Low Density Commercial Grant Ranch	Roads/Highway Moreno A RVTS	Roads/Highway Moreno B RVTS	Maintenance Station Mount Shasta	Roads/Highway Mount Gate Sand Filter Influents	Roads/Highway Murrieta RVTS	Roads/Highway Redding RVTS	Roads/Highway Sancramento RVTS	Roads/Highway San Onofre RVTS	Roads/Highway San Rafael RVTS	Roads/Highway Yorba Linda RVTS
	0.25			0.5					0.5	0.5	1.7	1.3	2.5
	0.25			0.5					0.06	0.5	1.3	0.5	0.5
	0.25			0.5					0.5	1.4	1.8	0.5	0.5
				2.7					0.2	0.5	20	0.5	0.5
									0.1	0.5	10	0.5	0.5
									0.035	0.5	32	1	3.4
									0.07	0.5	4.7	0.5	7.4
									0.035	0.5	15	0.5	2.1
									0.2	1.6	1.4	0.5	2.6
									0.15	1.4	1.3	0.5	0.5
									0.5	1.1	0.5	0.5	0.5
									0.5	0.5	0.5	0.5	4.3
									0.5	0.3	0.5	0.5	1
									0.5	0.2		0.5	2.1
									0.5	4.1		0.5	1.4
									0.5	0.035		3.6	0.5
									0.5	1			0.5
									0.06	0.5			0.5
									0.5	1.4			0.5
									0.5	0.5			0.2

Total Zn

Onsite	Medium Density Residential WQ Analysis Value	Roads/Highway Cottonwood RVTS	Office Commercial Elm Drive	Low Density Commercial Grant Ranch	Office Commercial IX-2	Office Commercial IX-3	Office Commercial IX-4	Office Commercial IX-5	Office Commercial IX-7	Roads/Highway Moreno A RVTS	Roads/Highway Moreno B RVTS	Maintenance Station Mount Shasha	Roads/Highway Mountain Gate	Roads/Highway Murrieta RVTS	Roads/Highway Redding RVTS	Roads/Highway Sacramento RVTS	Roads/Highway San Onofre RVTS	Roads/Highway San Rafael RVTS	Roads/Highway Yorba Linda RVST
407.59	254.1	93	12	25	125	125	21.5	50	125	800	96	43	41	69	32	77	46	180	520
532.05	500	98	43.4	25	125	25	10.5	77	25	630	96	35	69.6	37	36	59	56	330	910
328.48	520	98	14	136	25	36	8.3	48	27	340	130	10.4	105	32	8.4	60	240	180	310
639.78	230	110	11.3	25	50	25	8.1	41	44	230	55	20.5	86	110	22	78	220	140	570
390.12	170	120	9	25	58	15	8.5	27	32	210	46	130	82	33	53	29	250	120	610
345.96	180	97	12	40.4	35	17	10.1	22	23	150	66	29	93	44	15	41	440	91	640
419.19	550	81	8.9	70.2	21	9	8	26	17	190	58	170	12	57	20	50	270	150	94
333.83	340	67	12.4	34.8	15.7	11	9.1	26	54	240	120	13.9	28	17	32	22.5	180	80	180
596.35	180	91	4	31	32.9	20.5	14	33.9	19	370	77	1	43	19	21	97	360	100	160
652.49	140	310	4	23.5	30.5	8.9	12.6	31	12.5	300	64	49.3	120	8.7	27	40	100	120	130
	200	130	6	10	9.2	11	9.8	25	34	310	39	26.8	92	51	20	140	130	80	330
328.48	180	65	14	25	19	16.4	5.6	27	49	1000	65	32.5	66	24	28	69	260	140	150
652.49	270	230	12.5	52.7	17	7.6	10	189	38	640	51	65.4	101	30	130	81	250	130	160
	220	88	17	25	31.7	8.6	7.3	12.5	12.5		100	25.7	260	74	58	110	260	48	290
	140	120	13.1	25	13.7	9.2	25	31	12.5	110	75	22.2	110	24	34	31	210	58	190
	110	120	17.1	25	33.7	18	41	19.7	13.1	130		21.1	42	19	79	75	180	130	240
	240	220	17	15	13.4	12.9	20.5	15	24	79		39.1	9.7	22	6.6	11	410	250	520
	320	71	10	51.7	11.1	9	20	16.1	28	140		19.3	70		25	58	340	65	410

Total Zn

	Medium Density Residential	Roads/Highway	Office Commercial	Low Density Commercial	Office Commercial	Office Commercial	Office Commercial	Office Commercial	Office Commercial	Roads/Highway	Roads/Highway	Maintenance Station	Roads/Highway	Roads/Highway	Roads/Highway	Roads/Highway	Roads/Highway	Roads/Highway	Roads/Highway
Onsite	WQ Analysis Value	Cottonwood RVTS	Elm Drive	Grant Ranch	IX-2	IX-3	IX-4	IX-5	IX-7	Moreno A RVTS	Moreno B RVTS	Mount Shasha	Mountain Gate	Murrieta RVTS	Redding RVTS	Sacramento RVTS	San Onofre RVTS	San Rafael RVTS	Yorba Linda RVST
	270	120	14	63.4	6.3	7.1	10.9	18.5		120		62.3	54.8		19	170	220	130	340
	310	220	38	62.1	15.2	17	15.2			130		33.1	42.1		41	80	390	130	120
	250	110	91	170	11.5	11.2	21.7			46		43.2	41.5		19	74	120	54	200
	580	130	13.7	15			12.1			160		63.8	22.2		130	30	360	71	350
	200	42	15.8	15			19.2			630		54.8	71.7		17	31	73	160	65
	470	9.8	9	15						150		34.2	46.1		35	27	70	70	980
	290	11	43.4	15						250		32	52.4		40	21	120	44	53
	1500	2.5	14	15						80			150		16	21	100	59	550
	360	85	11.3	28						190			83		42	74	94	67	230
	240	117	9	111						44			41.5		18	38	20	65	100
	180	6.9	4	36.2						50			72.5		16	74	53	210	130
	170	6.2	6	10						170			62		7.3	50	75	86	260
	79	8.1	14	35.3						77			43		18	120	140	290	200
	500	5.6	17.1	79						55			10.7		21	73	140	130	430
	250	8.2	17	151						89			65		17	33	160	150	95
	480	13	14	29.8						125			24		21	280	57	57	110
	180	15	38	10						510			86		22	91	24	220	130
	180	7.3	91	10						260			9.7		28	120	36	9.4	93
	210	25	13.7	119						110			70		17	99	69	11	64

Total Zn

	Medium Density Residential	Roads/Highway	Office Commercial	Low Density Commercial	Office Commercial	Office Commercial	Office Commercial	Office Commercial	Office Commercial	Roads/Highway	Roads/Highway	Maintenance Station	Roads/Highway	Roads/Highway	Roads/Highway	Roads/Highway	Roads/Highway	Roads/Highway	Roads/Highway
Onsite	WQ Analysis Value	Cottonwood RVTS	Elm Drive	Grant Ranch	IX-2	IX-3	IX-4	IX-5	IX-7	Moreno A RVTS	Moreno B RVTS	Mount Shasha	Mountain Gate	Murrieta RVTS	Redding RVTS	Sacramento RVTS	San Onofre RVTS	San Rafael RVTS	Yorba Linda RVST
	63	10	9	63						150			69.6		9.1	89	90	14	170
	120	32	22	45.3						160			105		380	52	55	140	110
	190	36	17.3	96						79			54.8		8.1	22	340	41	110
	110	47	42.4	84.2						120			42.1		16	23	55	36	160
	170	37	12	81.3						140			41.5		8.6	40	87	12	180
	290	62	39	37						39			22.2		25	7.9	40	8.3	150
	420	35	16.4	68.1						47			71.7		9.1	44	37	13	250
	390	30	13.7	10						46			46.1		15	80	50	6	100
	220	29	32	26						75			83		12	12	160	9.6	68
	280		28	10						1800			260		450	31	67	41	54
	488		27.5	154						120					430	13	250	15	31
	350		15.7	80.7						220					34	15	42	53	92
	460									140					13	65	52	110	45
	260									200					7.6	28	30	12	84
	200									120					6.2	31	21	53	77
	330									320					6.8	40	27	830	68
	310									310					6	33	76	49	60
	530									86					13	58	68	22	98
	480									81					6.8	17	51	12	170

Total Zn

Onsite	Medium Density Residential WQ Analysis Value	Roads/Highway Cottonwood RVTS	Office Commercial Elm Drive	Low Density Commercial Grant Ranch	Office Commercial IX-2	Office Commercial IX-3	Office Commercial IX-4	Office Commercial IX-5	Office Commercial IX-7	Roads/Highway Moreno A RVTS	Roads/Highway Moreno B RVTS	Maintenance Station Mount Shasha	Roads/Highway Mountain Gate	Roads/Highway Murrieta RVTS	Roads/Highway Redding RVTS	Roads/Highway Sacramento RVTS	Roads/Highway San Onofre RVTS	Roads/Highway San Rafael RVTS	Roads/Highway Yorba Linda RVST
	150									73					16	48	64	11	80
	370									130					22	27	83	19	29
	200														12	100	89	12	92
	590														5.1	42	71	21	96
	190														8.9	39	24	16	44
	170														3.95	44	54	7.6	54
	160														8.6	16	20	19	21
	270														8.5	19	110	11	28
	310														20	74	35	68	34
	290														16.5	84	61	35	58
	370														6.2	27	94	31	20
	240														9.4	48		26	24
	280														22	41		29	31
	240														5.3	64		140	47
	480														11	63			27
	440														10	34			71
	1500														7.1	15			40
	340														2.5	21			130
	380														5.8	27			330

Total Zn

Onsite	Medium Density Residential WQ Analysis Value	Roads/Highway Cottonwood RVTS	Office Commercial Elm Drive	Low Density Commercial Grant Ranch	Office Commercial IX-2	Office Commercial IX-3	Office Commercial IX-4	Office Commercial IX-5	Office Commercial IX-7	Roads/Highway Moreno A RVTS	Roads/Highway Moreno B RVTS	Maintenance Station Mount Shasha	Roads/Highway Mountain Gate	Roads/Highway Murrieta RVTS	Roads/Highway Redding RVTS	Roads/Highway Sacramento RVTS	Roads/Highway San Onofre RVTS	Roads/Highway San Rafael RVTS	Roads/Highway Yorba Linda RVST
	230														2.9	11			87
	520														2.5	35			63
	80														2.5	12			32
	550														12	17			85
	280														14	14			440
	170														15	19			
	1200														5.6	27			
	200														32	19			
	320														2.5	30			
	99														25	32			
	200														19	10			
	340														12	26			
	140														26	18			
	130														53	44			
	230														10.5	28			
	320														6.7	11			
	290														5.5	34			
	710														9.2	27			

Dissolved Zn

UDFCD Modular Porous Pavement 94 to 04	I-5/SR-78 P&R	La Costa P&R	Lakewood P&R	Lakewood Shops	Fayetteville Filterra	Termination P&R	Via Verde P&R	I-95 Plaza Bioretention Cell	On-Site Data
30	65	28	601	23.4	30	72	33.3	51	392.15
40	35	25	90	9.2	28	16.5	23.4	49	457.42
20	29	220	190	3.4	13	130	47	34	397.03
10	5.8	50	32.7	11.5	15	27.2	57	38	768.64
40	10	81	81.3	22.3	28	135	87	104	389.35
30	24	23	53	15.3		55.5	23.5	24	326.55
20	26	120	120	12.8		27	44	42	399.17
20	23	100	41.6	2.5		60	118	12	343.69
10	44	16	148	2.5		81		41	588.38
20	21	110	59	2.5				51	642.56
10	82	18		38.6					
40	27	85		6.9					
60	88	170		2.5					
50	15	21		2.5					
10	59	19		2.5					
40	83	64		2.5					
10	31	45		26.5					
50	6.5			21.9					
40				2.5					
80				13.6					
10				2.5					
20				7.8					
50				2.5					
30				2.5					

Dissolved Zn

UDFCD Modular Porous Pavement 94 to 04	I-5/SR-78 P&R	La Costa P&R	Lakewood P&R	Lakewood Shops	Fayetteville Filterra	Termination P&R	Via Verde P&R	I-95 Plaza Bioretention Cell	On-Site Data
10				10					
10				2.5					
30				8.1					
10				2.5					
10				6					
10				8.7					
30				31.9					
20				2.5					
10				6.7					
10				2.5					
10				2.5					
40				2.5					
70				2.5					
10				2.6					
20				5.1					
20				2.5					
10				19.3					
20				2.5					
40				8.2					
10				12.9					
10				0.02					
10				0.04					
20				0.04					
10				0.02					
100				0.02					
30				0.03					

Dissolved Zn

UDFCD Modular Porous Pavement 94 to 04	I-5/SR-78 P&R	La Costa P&R	Lakewood P&R	Lakewood Shops	Fayetteville Filterra	Termination P&R	Via Verde P&R	I-95 Plaza Bioretention Cell	On-Site Data
10				0.04					
100				0.04					
20				0.02					
20				0.06					
10				0.02					
10				2.5					
20				0.02					
40				0.03					
30				0.02					
40				0.03					
20				0.02					
40				0.02					
20				0.02					
40				0.02					
10				0.0283					
30				2.5					
20				2.5					
10				2.5					
30				2.5					
60				2.5					
70				0.02					
10				0.05					
20				0.04					
30				2.5					
20				10					
80				10					

Dissolved Zn

UDFCD Modular Porous Pavement 94 to 04	I-5/SR-78 P&R	La Costa P&R	Lakewood P&R	Lakewood Shops	Fayetteville Filterra	Termination P&R	Via Verde P&R	I-95 Plaza Bioretention Cell	On-Site Data
10				20					
80				10					
10				10					
10				10					
10				10					
10				30					
20				10					
10				10					
10				10					
60				50					
20				60					
200				15					
10				5					
10				24.7					
20				5.4					
10				12					
10				5					
40				80.7					

Appendix B: Calculations

B1 – EMC calculations

$$EMC = \frac{\sum_{i=1}^{n} V_i C_i}{\sum_{i=1}^{n} V_i}$$

Arsenic

	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
Unfiltered Concentration	0.59	0.96	0.24	0.20	1.09	0.20	0.20	0.31	0.39	0.90
	0.44	0.62	0.27	0.21	0.81	0.20	0.20	0.18	0.26	0.46
	0.40	0.36	0.19	0.43	0.40	0.20	0.20	0.29	0.29	0.21
	0.30	0.23	0.26	0.40	0.31	0.20	0.20	0.25	0.34	0.24
	0.34	0.11	0.22	0.26	0.16	0.20	0.20	0.30	0.48	0.25
	0.39	0.11	0.17	0.21	0.19	0.20	0.20	0.15	0.41	0.24
	0.42	0.11	0.11	0.32	0.39	0.20	0.20	0.16	0.35	0.38
	0.50	0.13	0.11	0.17	0.14	0.20	0.20	0.36	0.19	0.36
	0.25	0.20	0.17	0.11	0.10	0.20	0.20	0.23	0.22	0.20
	0.11	0.21	0.17	0.18	0.16	0.20	0.20	0.34		
Dissolved concentration	0.52	2.01	0.28	0.22	1.07	0.20	0.20	0.19	0.37	1.04
	0.46	2.14	0.27	0.28	0.78	0.20	0.20	0.11	0.26	0.56
	0.35	1.00	0.20	0.40	0.40	0.20	0.20	0.18	0.24	0.14
	0.32	0.50	0.33	0.40	0.31	0.20	0.20	0.22	0.29	0.18
	0.31	0.50	0.19	0.23	0.26	0.20	0.20	0.22	0.40	0.31
	0.40	0.50	0.20	0.15	0.10	0.20	0.20	0.17	0.42	0.18
	0.41	0.50	0.28	0.27	0.25	0.20	0.20	0.15	0.46	0.34
	0.46	0.50	0.13	0.23	0.22	0.20	0.20	0.39	0.21	0.49
	0.27	0.50	0.15	0.24	0.20	0.20	0.20	0.18	0.28	0.18
	0.11	0.50	0.18	0.16	0.17	0.20	0.20	0.27		
Suspended particulates	-0.07	1.05	0.04	0.02	-0.01	0.00	0.00	-0.12	-0.02	0.13
	0.02	1.52	0.00	0.06	-0.03	0.00	0.00	-0.07	0.00	0.09
	-0.05	0.64	0.01	-0.03	-0.01	0.00	0.00	-0.11	-0.05	-0.08
	0.01	0.27	0.06	0.00	0.00	0.00	0.00	-0.03	-0.05	-0.07
	-0.03	0.39	-0.02	-0.03	0.10	0.00	0.00	-0.08	-0.08	0.06
	0.01	0.39	0.03	-0.05	-0.09	0.00	0.00	0.02	0.00	-0.06
	-0.01	0.39	0.17	-0.05	-0.14	0.00	0.00	-0.01	0.10	-0.04
	-0.04	0.37	0.02	0.06	0.08	0.00	0.00	0.03	0.02	0.13
	0.02	0.30	-0.02	0.13	0.10	0.00	0.00	-0.05	0.07	-0.02
	0.00	0.29	0.02	-0.02	0.00	0.00	0.00	-0.07	0.00	0.00
Suspended particulates adjusted	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**	**7th**	**8th**	**9th**	**10th**
		1.05	0.04	0.02						0.13
	0.02	1.52		0.06						0.09
		0.64	0.01							
	0.01	0.27	0.06							

		0.39			0.10					0.06
	0.01	0.39	0.03					0.02		
		0.39	0.17						0.10	
		0.37	0.02	0.06	0.08			0.03	0.02	0.13
	0.02	0.30		0.13	0.10				0.07	
		0.29	0.02							
	0.56	0.96	0.24	0.20	1.08	0.20	0.20	0.25	0.38	0.90
	0.44	0.62	0.27	0.21	0.79	0.20	0.20	0.15	0.26	0.46
	0.37	0.36	0.19	0.41	0.40	0.20	0.20	0.24	0.26	0.18
	0.30	0.23	0.26	0.40	0.31	0.20	0.20	0.24	0.32	0.21
	0.32	0.11	0.20	0.25	0.16	0.20	0.20	0.26	0.44	0.25
	0.39	0.11	0.17	0.18	0.15	0.20	0.20	0.15	0.41	0.21
	0.42	0.11	0.11	0.30	0.32	0.20	0.20	0.16	0.35	0.36
	0.48	0.13	0.11	0.17	0.14	0.20	0.20	0.36	0.19	0.36
	0.25	0.20	0.16	0.11	0.10	0.20	0.20	0.21	0.22	0.19
	0.11	0.21	0.17	0.17	0.16	0.20	0.20	0.31		
Runoff Volume	3719.84	18599.18	37198.36	14879.34	5579.75	83696.31	5579.75	40918.20	107875.24	0.00
	3719.84	18599.18	17669.22	22319.02	14879.34	9299.59	16739.26	1859.92	3719.84	92995.90
	3719.84	18599.18	54867.58	3719.84	14879.34	18599.18	7439.67	0.00	3719.84	74396.72
	7439.67	46497.95	54867.58	3719.84	14879.34	3719.84	0.00	1859.92	1859.92	37198.36
	7439.67	55797.54	54867.58	1859.92	7439.67	163672.78	3719.84	1859.92	3719.84	18599.18
	7439.67	9299.59	68816.97	55797.54	7439.67	33478.52	1859.92	3719.84	5579.75	55797.54
	0.00	18599.18	9299.59	92995.90	7439.67	27898.77	1859.92	9299.59	78116.56	18599.18
	55797.54	9299.59	0.00	9299.59	7439.67	9299.59	79046.52	22319.02	27898.77	111595.08
	18599.18	4649.80	1859.92	9299.59	1859.92	3719.84	79046.52	29758.69	9299.59	18599.18
	18599.18	4649.80	1859.92	9299.59	9299.59	37198.36	9299.59	31618.61		
total volume	170156	267388	99663	510468	267388	316004	221391	221087	559084	275949
volume X dissolved concentration	2066.84	17779.99	9008.07	2952.88	6027.24	16739.26	1115.95	10229.55	41005.24	0.00
	1649.67	11497.97	4715.98	4690.07	11798.86	1859.92	3347.85	269.69	980.77	43022.29
	1377.25	6760.72	10556.95	1535.09	5960.39	3719.84	1487.93	0.00	974.26	13160.39
	2258.18	10890.63	14531.24	1489.84	4590.27	743.97	0.00	437.08	592.03	7851.76
	2401.34	5989.36	11190.40	455.90	1207.03	32734.56	743.97	483.58	1634.43	4620.74

	2927.55	1056.58	11557.32	10160.72	1102.28	6695.70	371.98	557.98	2296.47	11754.57
	0.00	2033.35	1005.82	27530.86	2388.24	5579.75	371.98	1441.44	27703.17	6666.98
	26722.01	1218.00	0.00	1578.42	1077.32	1859.92	15809.30	8034.85	5287.59	40489.22
	4653.54	924.78	300.73	995.60	190.93	743.97	15809.30	6100.53	2010.17	3473.75
	1971.68	969.45	306.99	1593.12	1518.96	7439.67	1859.92	9643.67	0.00	0.00
sum(A) / Total volume	0.27	0.22	0.63	0.10	0.13	0.25	0.18	0.17	0.15	0.47
Volume X Total Concentration	1932.81	37335.93	10434.57	3200.34	5987.49	16739.26	1115.95	7774.46	39790.57	0.00
	1716.65	39748.67	4798.56	6138.03	11606.87	1859.92	3347.85	204.59	977.25	51712.58
	1284.04	18680.24	11062.22	1477.57	5898.60	3719.84	1487.93	0.00	885.14	10339.02
	2350.68	23248.98	18000.44	1482.17	4567.91	743.97	0.00	409.18	547.66	6594.02
	2279.25	27898.77	10549.38	430.97	1927.07	32734.56	743.97	409.18	1493.00	5790.34
	2978.31	4649.80	13865.17	8626.93	759.41	6695.70	371.98	632.37	2316.03	10038.92
	0.00	9299.59	2571.57	25102.23	1852.96	5579.75	371.98	1394.94	35597.24	6275.41
	25728.59	4649.80	0.00	2129.31	1664.04	1859.92	15809.30	8704.42	5758.85	54834.55
	4975.33	2324.90	278.36	2241.79	371.02	743.97	15809.30	5356.56	2633.28	3274.83
	2046.54	2324.90	336.13	1495.34	1549.70	7439.67	1859.92	8537.02	0.00	0.00
sum(B) / Total volume	0.27	0.64	0.72	0.10	0.14	0.25	0.18	0.15	0.16	0.54

EMC calculations for Cd

Sampling day	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**	**7th**	**8th**	**9th**	**10th**
Filtered	0.2	0.5	0.9	1.0	0.7	0.1	0.2	0.0	0.1	0.2
	0.0	0.3	0.6	0.5	0.5	0.1	0.5	0.0	0.1	0.1
	0.0	0.6	0.9	0.6	0.2	0.1	0.1	0.1	0.1	0.1
	0.0	0.6	0.6	0.5	0.2	0.1	0.1	0.1	0.1	0.0
	0.0	0.3	0.6	0.7	0.4	0.1	0.2	0.1	0.1	0.1
	0.0	0.3	0.6	0.6	0.3	0.1	0.1	0.0	0.1	0.1
	0.1	0.3	0.6	0.8	0.3	0.2	0.1	0.1	0.1	0.1
	0.1	0.3	0.4	0.4	0.2	0.2	0.1	0.1	0.1	0.3
	0.1	0.4	0.5	0.5	0.2	0.1	0.1	0.1	0.1	1.1
	0.0	0.2	0.7	0.6	0.2		0.1	0.1		
Unfiltered	0.2	0.5	0.3	0.2	0.4	0.1	0.2	0.0	0.1	0.2
	0.1	0.4	0.5	0.3	0.3	0.1	0.5	0.0	0.1	0.1
	0.1	0.4	0.3	0.6	0.2	0.2	0.1	0.0	0.1	0.0
	0.0	0.4	0.9	0.5	0.1	0.3	1.0	0.1	0.1	0.0
	0.1	0.2	0.4	0.3	0.2	0.1	0.4	0.1	0.1	0.1
	0.1	0.1	0.4	0.2	0.1	0.1	0.5	0.0	0.1	0.1
	0.1	0.3	0.2	0.4	0.1	0.2	0.0	0.0	2.1	0.1
	0.1	0.3	0.2	0.3	0.1	0.4	0.2	0.1	0.1	0.3
	0.1	0.8	0.4	0.3	0.1	0.3	0.1	0.0	0.1	1.2
	0.0	0.3	0.4	0.1	0.1	0.3	0.1	0.0		
suspended	0.0	0.0	-0.5	-0.7	-0.3	0.0	0.0	0.0	0.0	0.0
	0.0	0.1	0.0	-0.2	-0.2	0.0	0.0	0.0	0.0	0.0
	0.0	-0.2	-0.6	-0.1	0.0	0.1	0.0	0.0	0.0	0.0
	0.0	-0.2	0.3	0.1	-0.2	0.2	0.9	0.0	-0.1	0.0
	0.0	-0.1	-0.2	-0.4	-0.2	0.0	0.3	0.0	0.0	0.0
	0.0	-0.2	-0.2	-0.4	-0.3	0.0	0.3	0.0	0.0	0.0
	0.0	0.0	-0.4	-0.5	-0.2	0.0	-0.1	0.0	1.9	0.0
	0.0	-0.1	-0.3	-0.1	-0.1	0.2	0.1	0.0	0.0	0.0
	0.0	0.4	0.0	-0.2	-0.2	0.2	0.0	0.0	0.0	0.0
	0.0	0.1	-0.3	-0.5	-0.1	0.3	0.0	0.0	0.0	0.0
Sus adjusted	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
	0.0	0.0	0.3	0.1	0.0	0.2	0.9	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	0.0
	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.0
	0.0	0.4	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
	0.0	0.1	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0

dissolved	0.2	0.5	0.6	0.6	0.6	0.1	0.2	0.0	0.1	0.2
	0.0	0.3	0.5	0.4	0.4	0.1	0.5	0.0	0.1	0.1
	0.0	0.5	0.6	0.6	0.2	0.1	0.1	0.0	0.1	0.0
	0.0	0.5	0.6	0.5	0.2	0.1	0.1	0.1	0.1	0.0
	0.0	0.2	0.5	0.5	0.3	0.1	0.2	0.1	0.1	0.1
	0.0	0.2	0.5	0.4	0.2	0.1	0.1	0.0	0.1	0.1
	0.1	0.3	0.4	0.6	0.2	0.2	0.1	0.0	0.1	0.1
	0.1	0.3	0.3	0.4	0.1	0.2	0.1	0.1	0.1	0.3
	0.1	0.4	0.4	0.4	0.2	0.1	0.1	0.0	0.1	1.1
	0.0	0.2	0.5	0.4	0.1		0.1	0.0		
EMC										
volume	37198	0.0	0.0	7439.7	0.0	83696	5579.8	40918	111595	0.0
	17669	18599	18599	27899	0.0	27899	9299.6	1859.9	0.0	92996
	54867.6	18599.2	9299.6	7439.7	14879.3	3719.8	7439.7	0.0	3719.8	74396.7
	54867.6	18599.2	27898.8	14879.3	9299.6	163672.8	0.0	0.0	1859.9	37198.4
	54867.6	9299.6	46498.0	3719.8	13019.4	33478.5	3719.8	1859.9	3719.8	18599.2
	68817.0	9299.6	65097.1	55797.5	18599.2	27898.8	1859.9	1859.9	5579.8	55797.5
	9299.6	18599.2	18599.2	92995.9	0.0	9299.6	1859.9	3719.8	78116.6	18599.2
	0.0	9299.6	5579.8	9299.6	9299.6	3719.8	148793.4	9299.6	27898.8	111595.1
	1859.9	9299.6	3719.8	9299.6	9299.6	37198.4	9299.6	52077.7	9299.6	18599.2
	1859.9	18599.2	9299.6	9299.6	1859.9	37198.4	9299.6	31618.6	0.0	0.0
total volume	301306.7	130194.3	204591.0	238069.5	76256.6	427781.1	197151.3	143213.7	241789.3	427781.1
A **volume X dissolved concentration**	8022.9	0.0	0.0	4429.5	0.0	8369.6	1251.5	1227.5	10401.5	0.0
	853.2	5791.7	9815.4	12360.9	0.0	2789.9	4593.1	37.2	0.0	6462.3
	2091.4	9461.3	5385.7	4484.4	2377.4	372.0	744.0	0.0	314.3	2444.8
	1712.7	10053.8	16726.2	6808.3	1566.1	20405.5	0.0	0.0	207.5	1407.7
	2659.5	2255.8	22395.3	2016.0	3979.4	3313.3	571.3	148.8	428.8	935.3
	3415.8	1966.2	33310.9	23102.4	3567.9	2789.9	233.1	74.4	596.7	2905.4
	708.0	5004.1	7024.9	56535.6	0.0	1912.5	110.3	130.2	11716.3	1395.7
	0.0	2674.0	1720.1	3485.8	1196.1	774.5	14151.8	697.5	1410.4	35570.0
	117.0	3562.5	1638.1	3672.8	1529.1	4470.3	930.0	2083.1	691.2	21240.6
	44.2	3668.2	4989.3	3614.8	225.8	0.0	930.0	1264.7	0.0	0.0

	sum(A) / Total volume	0.1	0.3	0.5	0.5	0.2	0.1	0.1	0.0	0.1	0.2
B	**Volume X Total Concentration**	7924.6	0.0	0.0	1754.4	0.0	8369.6	1151.1	1227.5	9820.4	0.0
		1102.5	7241.5	9394.4	9644.4	0.0	2789.9	4452.6	55.8	0.0	5969.6
		3339.3	7197.7	2395.8	4171.5	2844.9	817.6	765.0	0.0	252.2	637.1
		2542.1	8101.7	24977.3	7961.5	841.2	57116.7	0.0	0.0	156.6	1106.1
		2817.5	2018.0	18775.6	1289.7	2781.0	3347.9	1573.0	130.2	344.2	1205.9
		4812.6	1142.3	28404.1	12814.9	1142.4	2789.9	854.7	74.4	611.0	3014.5
		879.7	5683.9	3510.7	34317.8	0.0	1685.3	34.7	74.4	160704.5	1588.1
		0.0	2357.5	936.3	3122.6	833.3	1625.6	27443.7	558.0	2114.2	35764.5
		171.3	7728.5	1554.0	2875.2	749.7	11594.4	930.0	1562.3	855.4	21452.9
		45.9	6351.7	3694.5	1255.6	140.3	9634.1	930.0	948.6	0.0	0.0
	sum(B) / Total volume	0.1	0.4	0.5	0.3	0.1	0.2	0.2	0.0	0.7	0.2
C	**Vol x sus conc**	8022.9	0.0	0.0	4429.5	0.0	8369.6	1251.5	1227.5	10401	0.0
		853.2	5791.7	9815.4	12361	0.0	2789.9	4593.1	37.2	0.0	6462.3
		2091.4	9461.3	5385.7	4484.4	2377	372.0	744.0	0.0	314.3	2444.8
		1712.7	10054	16726	6808.3	1566	20406	0.0	0.0	207.5	1407.7
		2659.5	2255.8	22395	2016.0	3979	3313.3	571.3	148.8	428.8	935.3
		3415.8	1966.2	33311	23102	3568	2789.9	233.1	74.4	596.7	2905.4
		708.0	5004.1	7024.9	56536	0.0	1912.5	110.3	130.2	11716	1395.7
		0.0	2674.0	1720.1	3485.8	1196	774.5	14152	697.5	1410.4	35570
		117.0	3562.5	1638.1	3672.8	1529	4470.3	930.0	2083.1	691.2	21241
		44.2	3668.2	4989.3	3614.8	225.8	0.0	930.0	1264.7	0.0	0.0
	sum(C)/Total volume	0.1	0.3	0.5	0.5	0.2	0.1	0.1	0.0	0.1	0.2

EMC calculations for Cu

	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
Filtered										
	9.56	17.43	20.84	21.27	11.60	1.48	2.30	5.07	5.93	10.89
	4.69	8.56	17.95	39.82	7.73	0.46	1.23	1.84	5.37	5.28
	5.42	9.78	15.30	24.28	3.08	0.66	1.75	2.61	5.48	3.53
	3.57	7.08	9.59	13.58	3.16	1.25	0.79	3.41	6.70	4.81
	14.48	10.20	13.81	41.08	1.88	0.67	5.66	3.11	5.86	3.14
	5.28	3.72	51.58	42.61	1.10	0.13	1.58	1.70	6.64	2.36
	5.77	7.74	6.12	23.60	2.13	0.43	1.04	2.22	6.82	3.76
	6.02	3.83	4.86	13.28	1.02	0.38	0.29	3.83	4.89	5.04
	4.58	10.15	17.54	9.30	1.18	0.77	0.47	2.58	2.00	2.71
	1.78	6.79	6.91	40.36	1.12		0.66	2.97		0.00
Unfiltered	7.11	21.0	18.08	10.46	22.83	1.12	2.31	4.39	4.170	12.36
	4.10	21.5	6.36	37.44	16.71	0.47	2.86	1.54	2.825	4.76
	4.19	30.0	6.17	18.97	9.34	0.71	1.41	2.16	3.301	1.30
	3.14	8.0	36.15	18.01	5.13	0.83	0.69	3.17	3.952	1.46
	13.48	29.6	12.44	12.03	5.11	0.81	4.34	2.77	4.411	3.53
	5.91	7.4	7.06	9.61	10.28	0.22	3.23	1.84	5.219	1.46
	5.22	34.0	6.76	33.37	4.28	0.50	0.96	1.94	17.172	3.62
	5.32	10.1	18.36	13.11	18.51	1.17	0.49	3.74	3.029	6.53
	4.48	25.2	16.18	12.65	22.46	2.09	0.46	1.51	7.809	2.43
	1.88	31.8	41.36	5.90	2.39	1.27	0.69	2.19		
Suspended	-2.45	3.54	-2.77	-10.81	11.23	-0.36	0.00	-0.68	-1.76	1.47
	-0.59	12.98	-11.59	-2.38	8.98	0.00	1.63	-0.30	-2.55	-0.52
	-1.24	20.22	-9.13	-5.31	6.26	0.05	-0.34	-0.45	-2.18	-2.23
	-0.43	0.92	26.56	4.42	1.98	-0.41	-0.10	-0.24	-2.75	-3.35
	-1.01	19.37	-1.37	-29.05	3.23	0.14	-1.32	-0.34	-1.45	0.39
	0.63	3.69	-44.52	-33.00	9.19	0.09	1.65	0.14	-1.43	-0.90
	-0.55	26.26	0.63	9.77	2.15	0.07	-0.07	-0.28	10.35	-0.15
	-0.70	6.27	13.50	-0.17	17.49	0.78	0.20	-0.09	-1.86	1.48
	-0.10	15.09	-1.36	3.35	21.28	1.32	-0.01	-1.07	5.81	-0.28
	0.09	25.05	34.45	-34.47	1.26		0.03	-0.78		0.00
Sus Corrected	0	3.5437	0	0	11.232	0	0.0041	0	0	1.4703
	0	12.985	0	0	8.9796	0.0036	1.6310	0	0	0
	0	20.217	0	0	6.2617	0.0472	0	0	0	0
	0	0.9207	26.561	4.4226	1.9765	0	0	0	0	0
	0	19.367	0	0	3.2305	0.140	0	0	0	0.3861
	0.625908	3.694707	0	0	9.189905	0.086801	1.652334	0.14	0	0
	0	26.256	0.6340	9.7729	2.1470	0.0692	0	0	10.351	0
	0	6.2726	13.498	0	17.486	0.7841	0.2031	0	0	1.4835
	0	15.086	0	3.3463	21.275	1.3171	0	0	5.8129	0
	0.0921	25.055	34.451	0	1.2641		0.0286	0		0

	Dissolved	8.3373	17.431	19.461	15.862	11.60	1.2999	2.3028	4.73	5.0504	10.892
		4.3980	8.5595	12.156	38.632	7.7256	0.4643	1.2265	1.69	4.0991	5.0214
		4.8061	9.7825	10.732	21.621	3.0797	0.6594	1.5838	2.385	4.3888	2.4191
		3.3594	7.0849	9.5923	13.584	3.1563	1.0409	0.7403	3.29	5.3256	3.1365
		13.979	10.204	13.129	26.554	1.8813	0.6705	4.9966	2.94	5.1361	3.1402
		5.2848	3.7191	29.319	26.107	1.0951	0.1324	1.5766	1.7	5.9315	1.9065
		5.4925	7.7443	6.1211	23.597	2.1311	0.4271	1.0024	2.08	6.8209	3.6913
		5.6652	3.8339	4.8576	13.191	1.0242	0.3816	0.2861	3.785	3.9590	5.0447
		4.5305	10.145	16.858	9.3035	1.1846	0.7690	0.4657	2.045	1.9965	2.5717
		1.7843	6.7935	6.9078	23.129	1.1238		0.6578	2.58		
EMC	**volume**	37198	0	0	7439.7	0	83696	5579.8	40918	111595	0
		17669	18599	18599	27899	0	27899	9299.6	1859.9	0	92996
		54868	18599	9299.6	7439.7	14879	3719.8	7439.7	0	3719.8	74397
		54868	18599	27899	14879	9299.6	163673	0	0	1859.9	37198
		54868	9299.6	46498	3719.8	13019	33479	3719.8	1859.9	3719.836	18599.18
		68817	9299.6	65097	55798	18599	27899	1859.9	1859.9	5579.754	55797.54
		9299.6	18599	18599	92996	0	9299.6	1859.9	3719.8	78116.56	18599.18
		0	9299.6	5579.8	9299.6	9299.6	3719.8	148793	9299.6	27898.77	111595.1
		1859.9	9299.6	3719.8	9299.6	9299.6	37198	9299.6	52078	9299.59	18599.18
		1859.9	18599	9299.6	9299.6	1859.9	37198	9299.6	31619	0	0
	total volume	301307	130194	204591	238070	76257	427781	197151	143214	241789	427781
A	**volume X dissolved concentration**	310134	0	0	118004	0	108795	12849	193543	563602	0
		77709	159199	226087	1077782	0	12954	11406	3143.3	0	466968
		263697	181947	99801	160851	45824	2453.0	11783	0	16326	179974
		184320	131773	267614	202127	29353	170366	0	0	9905.2	116672
		766998	94891	610482	98777	24493	22448	18586	5468.2	19105	58406
		363685	34586	1908599	1456724	20367	3694.7	2932.3	3161.9	33096	106378
		51078	144037	113847	2194449	0	3971.6	1864.4	7737.3	532829	68655
		0	35654	27104	122672	9525.2	1419.4	42577	35199	110452	562962
		8426.4	94345	62709	86518	11016	28606	4330.8	106499	18566	47835
		3318.7	126354	64240	215088	2090.1	0	6116.8	81576	0	0

	sum(A) / Total volume	6.7352	7.7022	16.523	24.081	1.8709	0.8292	0.5703	3.0467	5.3926	3.7586
B	**Volume X Total Concentration**	264539.5	0	0	77785.42	0	93564.33	12872.09	179630.9	465312.3	0
		72479	400708	118290.8	1044557	0	13055.32	26573.19	2864.274	0	442597.1
		229773	557975	57342	141096	138994	2628.6	10511	0	12279	97025
		172551	148897	1008643	267931	47733.33	136457.2	0	0	7350.136	54426.79
		739376	275000	578658	44752	66552	27134	16129	5152	16407	65588
		406758	68946	459424	536118	191292	6116.3	6005.5	3422.2	29119	81215
		48506	632372	125639.4	3103288	0	4614.8	1794.66	7216.482	1341388	67286
		0	93986	102420	121881	172140	4336.1	72802	34780	84503	728514
		8332.2	234635	60178	117637	208867	77599	4288.3	78637	72624	45229
		3490	592356	384618	54826	4441.2	47078	6382.8	69245	0	0
	sum(B) / Total volume	6.45789	23.07994	14.15122	23.14396	10.88455	0.9645	0.798163	2.66	8.391525	3.697874
C	**Volume x suspended**	0	0	0	0	0	0	22.80211	0	0	0
		0	241509	0	0	0	100.94	15168	0	0	0
		0	376029	0	0	93170	175.55	0	0	0	0
		0	17124	741029	65805	18381	0	0	0	0	0
		0	180109	0	0	42059	4685.7	0	0	0	7182.0
		43073	34359	0	0	170925	2421.6	3073.2	260.39	0	0
		0	488335	11792	908839	0	643.16	0	0	808559	0
		0	58332	75316	0	162614	2916.7	30225	0	0	165552
		0	140290	0	31119	197851	48993	0	0	54058	0
		171.31	466002	320379	0	2351.1	0	265.92	0	0	0
	EMC = Sum (C)/ Total Vol	0.1435	15.378	5.6138	4.2247	9.0137	0.1401	0.2473	0.0018	3.5676	0.4038

EMC calculations of Pb

Filtered	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**	**7th**	**8th**	**9th**	**10th**
	11.5	6.1	2.1	1.0	8.0	0.8	0.7	3.5	5.0	1.4
	4.1	4.0	3.8	2.8	4.1	0.7	0.3	2.0	4.8	12.3
	3.5	1.2	1.4	1.6	1.8	0.3	0.5	3.0	2.4	3.0
	1.9	1.1	1.4	4.0	1.3	0.7	0.2	1.5	3.0	2.5
	1.6	0.4	1.2	1.9	1.1	9.3	0.2	3.2	5.5	19.5
	2.1	0.5	3.3	1.0	0.9	1.3	0.4	2.4	2.9	2.4
	2.7	0.5	1.5	1.5	1.0	1.5	0.5	1.7	19.6	4.2
	3.1	0.5	0.9	1.1	1.3	0.3	0.6	7.5	10.2	210.8
	8.0	0.5	1.0	1.7	1.3	0.3	0.3	0.6	4.1	12.3
	0.9	0.6	0.9	6.1	2.1		0.3	0.4		
Unfiltered	4.4	11.0	3.5	6.8	25.7	0.8	0.7	4.7	5.6	22.8
	1.9	20.5	4.7	6.8	12.7	0.7	0.1	2.9	7.0	21.1
	1.8	7.3	3.0	4.1	5.5	0.3	0.4	4.0	3.1	3.7
	1.2	5.1	3.6	7.6	4.0	0.3	0.2	2.0	2.9	3.5
	0.6	4.0	3.2	3.7	4.0	9.5	0.3	3.7	7.6	32.3
	1.2	2.6	3.4	1.9	3.6	1.3	0.4	3.5	4.3	3.7
	1.1	2.3	3.4	3.8	3.0	1.4	0.5	2.7	30.0	5.5
	1.4	2.1	3.2	3.7	4.9	0.2	0.7	12.6	15.7	318.6
	4.1	2.6	3.4	4.7	4.7	0.3	0.3	1.5	3.8	20.1
	0.4	2.2	4.0	5.9	6.1	0.4	0.3	1.3		
Suspended	-7.1	4.9	1.4	5.7	17.8	0.0	0.0	1.2	0.6	21.4
	-2.2	16.5	0.9	4.0	8.7	0.0	-0.1	0.9	2.1	8.8
	-1.7	6.1	1.6	2.6	3.6	0.0	0.0	1.0	0.7	0.6
	-0.7	4.0	2.2	3.7	2.6	-0.4	0.0	0.5	-0.1	0.9
	-1.0	3.6	2.0	1.8	2.9	0.2	0.0	0.4	2.1	12.8
	-0.9	2.2	0.1	0.9	2.7	0.1	0.0	1.2	1.4	1.2
	-1.6	1.9	1.9	2.3	2.0	-0.1	0.0	1.0	10.4	1.3
	-1.7	1.6	2.4	2.6	3.6	0.0	0.1	5.1	5.5	107.8
	-3.9	2.1	2.4	2.9	3.4	0.1	0.0	0.8	-0.4	7.8
	-0.5	1.6	3.2	-0.3	4.0	0.4	0.0	1.0	0.0	0.0
Suspended Corrected	0.0	4.9	1.4	5.7	17.8	0.0	0.0	1.2	0.6	21.4
	0.0	16.5	0.9	4.0	8.7	0.0	0.0	0.9	2.1	8.8
	0.0	6.1	1.6	2.6	3.6	0.0	0.0	1.0	0.7	0.6
	0.0	4.0	2.2	3.7	2.6	0.0	0.0	0.5	0.0	0.9
	0.0	3.6	2.0	1.8	2.9	0.2	0.0	0.4	2.1	12.8
	0.0	2.2	0.1	0.9	2.7	0.1	0.0	1.2	1.4	1.2
	0.0	1.9	1.9	2.3	2.0	0.0	0.0	1.0	10.4	1.3
	0.0	1.6	2.4	2.6	3.6	0.0	0.1	5.1	5.5	107.8
	0.0	2.1	2.4	2.9	3.4	0.1	0.0	0.8	0.0	7.8
	0.0	1.6	3.2	0.0	4.0	0.4	0.0	1.0	0.0	0.0

Dissolved		7.9	6.1	2.1	1.0	8.0	0.8	0.7	3.5	5.0	1.4
		3.0	4.0	3.8	2.8	4.1	0.7	0.2	2.0	4.8	12.3
		2.6	1.2	1.4	1.6	1.8	0.3	0.4	3.0	2.4	3.0
		1.5	1.1	1.4	4.0	1.3	0.5	0.2	1.5	3.0	2.5
		1.1	0.4	1.2	1.9	1.1	9.3	0.2	3.2	5.5	19.5
		1.7	0.5	3.3	1.0	0.9	1.3	0.4	2.4	2.9	2.4
		1.9	0.5	1.5	1.5	1.0	1.5	0.5	1.7	19.6	4.2
		2.3	0.5	0.9	1.1	1.3	0.2	0.6	7.5	10.2	210.8
		6.1	0.5	1.0	1.7	1.3	0.3	0.3	0.6	3.9	12.3
		0.6	0.6	0.9	6.0	2.1		0.3	0.4		
EMC	**volume**	37198.4	0.0	0.0	7439.7	0.0	83696.3	5579.8	40918.2	111595.1	0.0
		17669.2	18599	18599	27899	0.0	27899	9299.6	1859.9	0.0	92995.9
		54867.6	18599	9299.6	7439.7	14879	3719.8	7439.7	0.0	3719.8	74396.7
		54867.6	18599	27899	14879	9300	163672.8	0.0	0.0	1859.9	37198.4
		54867.6	9299.6	46498	3719.8	13019	33479	3719.8	1859.9	3719.8	18599.2
		68817.0	9299.6	65097	55798	18599	27899	1859.9	1859.9	5579.8	55797.5
		9299.6	18599	18599	92996	0.0	9299.6	1859.9	3719.8	78116.6	18599.2
		0.0	9299.6	5579.8	9299.6	9300	3719.8	148793.4	9299.6	27898.8	111595
		1859.9	9299.6	3719.8	9299.6	9300	37198	9299.6	52078	9299.6	18599.2
		1859.9	18599	9299.6	9299.6	1860	37198	9299.6	31619	0.0	0.0
	total volume	301306.7	130194.3	204591.0	238069.5	76256.6	427781.1	197151.3	143213.7	241789.3	427781.1
A	**volX diss conc**	295430.4	0.0	0.0	7764.5	0.0	64797.2	3958.3	141986.1	557398.2	0.0
		52929.4	74727	70440	76931	0.0	19439	1690.0	3719.8	0.0	1146143
		143238.1	23028	12762	11648	27384	1102.6	3176.8	0.0	8789.6	226575
		84119.9	20673	39683	59281	12264	86587	0.0	0.0	5539.9	94050.2
		61857.9	4119.3	57740	7005.1	14896	311250	919.0	6007.5	20343.7	362001
		114595.7	4361.4	213691	54758	16500	34917	768.4	4370.8	16105.9	136078
		17770.0	8661.1	27455.7	143443.1	0.0	13866.4	908.5	6286.5	1532146.8	78436.3
		0.0	4351.9	4829.1	10198	12396	869.5	87261	70026	284890	23523126.9
		11254.0	4188.8	3836.7	16256	11734	9962.5	2324.9	32809	36617.3	228224
		1172.0	11317	7980.9	55755	3824	0.0	2324.9	11383	0.0	0.0

	sum(A) / Tot vol	2.6	1.2	2.1	1.9	1.3	1.3	0.5	1.9	10.2	60.3
B	**Vol X Total Conc**	164021.7	0.0	0.0	50271.1	0.0	64205.1	3939.5	192724.7	623002.5	0.0
		33237.2	381971.8	87600.7	189728.3	0.0	19329.8	1055.0	5431.0	0.0	1966830.1
		97052.2	136429.8	27664.0	30675.0	81465.3	1124.1	2997.9	0.0	11409.3	274661.7
		65405.7	95697.3	99987.7	113621.8	36846.9	51020.0	0.0	0.0	5409.2	129276.1
		34819.7	37547.1	149116.6	13800.8	52177.5	317627.1	965.2	6788.7	28155.4	600939.7
		85127.2	24412.9	219443.0	106756.1	67262.2	36455.8	748.7	6584.1	24071.9	205367.6
		10459.5	43179.5	63119.9	355224.6	0.0	13399.3	923.8	10006.4	2342575.2	102402.1
		0.0	19170.6	17958.3	34003.0	45596.4	809.1	105373.4	117546.8	438803.5	35557540.3
		7611.0	23958.2	12644.8	43338.7	43283.5	12993.8	2324.9	76554.2	34894.6	373460.1
		717.1	40386.1	37280.0	54435.5	11286.8	15252.4	2324.9	41420.4	0.0	0.0
	sum(B) / Tot vol	1.7	6.2	3.5	4.2	4.4	1.2	0.6	3.2	14.5	91.7
C	**Vol x sus conc**	0.0	0.0	0.0	42506.6	0.0	0.0	0.0	50738.6	65604.3	0.0
		0.0	307245	17160	112797	0.0	0.0	0.0	1711.1	0.0	820687.0
		0.0	113402	14902	19027	54081	21.5	0.0	0.0	2619.7	48087.2
		0.0	75025	60305	54340	24583	0.0	0.0	0.0	0.0	35225.9
		0.0	33428	91377	6795.7	37282	6377.0	46.2	781.2	7811.7	238938.3
		0.0	20052	5751.6	51998	50763	1538.4	0.0	2213.3	7966.0	69290.0
		0.0	34519	35664	211781	0.0	0.0	15.3	3719.8	810428	23965.9
		0.0	14819	13129	23805	33201	0.0	18112	47521	153914	12034413
		0.0	19770	8808.1	27083	31549	3031.4	0.0	43745	0.0	145236.1
		0.0	29069	29299	0.0	7463	15252	0.0	30038	0.0	0.0
EMC = Sum (C)/ Total Vol		0.0	5.0	1.4	2.3	3.1	0.1	0.1	1.3	4.3	31.4

EMC calculation of Zn

	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
Filtered	483.7	1338.2	597.7	424.6	2353.5	308.3	424.5	272.0	799.5	1379.1
	337.4	957.4	655.7	538.1	1406.0	302.8	257.4	309.0	517.5	369.4
	318.7	448.1	491.4	1115.6	486.1	463.5	362.3	422.0	613.7	177.9
	274.3	232.4	709.7	1261.8	477.0	509.2	280.0	553.0	714.0	413.2
	405.6	255.8	444.5	528.2	380.5	129.6	413.1	758.0	805.4	369.9
	480.1	323.1	321.1	430.6	367.7	212.0	418.6	256.0	672.9	512.8
	560.5	176.6	490.0	1434.7	482.3	329.4	504.6	315.0	422.5	750.9
	581.5	425.9	377.7	485.8	286.2	381.5	403.0	334.0	200.9	1430.4
	460.6	597.5	376.0	230.3	349.6	249.4	484.7	338.0	644.5	299.4
	181.6	586.3	483.9	252.7	414.9		388.4	487.0		
Unfiltered	482.5	1521.7	413.1	310.1	2348	287.5	424.6	258.0	769.3	1583.5
	356.8	1133.6	460.0	369.0	1357	298.7	257.9	258.0	566.1	398.3
	324.1	512.0	338.9	809.2	479.6	449.6	355.7	369.0	608.0	150.2
	284.4	263.5	509.0	926.7	458.1	477.9	277.7	503.0	707.6	353.8
	442.0	316.3	316.9	368.2	419.9	127.6	417.8	749.0	686.2	403.5
	497.4	362.2	221.3	301.3	351.5	209.0	448.2	312.0	769.2	491.3
	586.6	192.2	342.2	1025.5	440.9	320.9	520.6	340.0	460.4	760.1
	630.9	448.9	279.6	348.8	266.3	374.6	429.4	338.0	201.9	1456.7
	497.7	716.5	272.4	166.3	346.7	258.5	475.0	314.0	679.0	329.2
	169.2	701.1	346.0	168.2	348.7	312.0	382.8	444.0		
Suspended	-1.2	183.5	-184.6	-114.5	-5.8	-20.7	0.1	-14.0	-30.2	204.3
	19.5	176.2	-195.8	-169.1	-48.7	-4.0	0.5	-51.0	48.7	29.0
	5.4	64.0	-152.5	-306.4	-6.4	-13.9	-6.6	-53.0	-5.6	-27.7
	10.1	31.1	-200.6	-335.1	-18.9	-31.3	-2.3	-50.0	-6.4	-59.3
	36.3	60.5	-127.6	-160.0	39.4	-2.1	4.7	-9.0	-119.2	33.6
	17.3	39.1	-99.8	-129.3	-16.2	-3.0	29.6	56.0	96.3	-21.5
	26.1	15.6	-147.8	-409.2	-41.4	-8.5	16.0	25.0	37.9	9.2
	49.4	23.0	-98.1	-137.0	-19.9	-6.9	26.4	4.0	1.1	26.4
	37.0	119.0	-103.6	-63.9	-2.9	9.1	-9.8	-24.0	34.5	29.8
	-12.4	114.7	-137.9	-84.4	-66.2	312.0	-5.5	-43.0	0.0	0.0
Suspend Adjusted	0.0	183.5	0.0	0.0	0.0	0.0	0.1	0.0	0.0	204.3
	19.5	176.2	0.0	0.0	0.0	0.0	0.5	0.0	48.7	29.0
	5.4	64.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	10.1	31.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	36.3	60.5	0.0	0.0	39.4	0.0	4.7	0.0	0.0	33.6
	17.3	39.1	0.0	0.0	0.0	0.0	29.6	56.0	96.3	0.0
	26.1	15.6	0.0	0.0	0.0	0.0	16.0	25.0	37.9	9.2
	49.4	23.0	0.0	0.0	0.0	0.0	26.4	4.0	1.1	26.4
	37.0	119.0	0.0	0.0	0.0	9.1	0.0	0.0	34.5	29.8
	0.0	114.7	0.0	0.0	0.0	312.0	0.0	0.0	0.0	0.0

Dissolved	483.1	1338.2	505.4	367.3	2350.6	297.9	424.5	265.0	784.4	1379.1
	337.4	957.4	557.9	453.6	1381.7	300.8	257.4	283.5	517.5	369.4
	318.7	448.1	415.1	962.4	482.9	456.6	359.0	395.5	610.8	164.1
	274.3	232.4	609.3	1094.3	467.5	493.6	278.9	528.0	710.8	383.5
	405.6	255.8	380.7	448.2	380.5	128.6	413.1	753.5	745.8	369.9
	480.1	323.1	271.2	366.0	359.6	210.5	418.6	256.0	672.9	502.1
	560.5	176.6	416.1	1230.1	461.6	325.1	504.6	315.0	422.5	750.9
	581.5	425.9	328.6	417.3	276.3	378.1	403.0	334.0	200.9	1430.4
	460.6	597.5	324.2	198.3	348.1	249.4	479.9	326.0	644.5	299.4
	175.4	586.3	415.0	210.4	381.8		385.6	465.5		
EMC										
volume	37198.4	0.0	0.0	7439.7	0.0	83696.3	5579.8	40918.2	111595.1	0.0
	17669.2	18599.2	18599.2	27898.8	0.0	27898.8	9299.6	1859.9	0.0	92995.9
	54867.6	18599.2	9299.6	7439.7	14879.3	3719.8	7439.7	0.0	3719.8	74396.7
	54868	18599	27899	14879.3	9299.6	163673	0.0	0.0	1859.9	37198.4
	54868	9299.6	46498	3719.8	13019	33479	3719.8	1859.9	3719.8	18599.2
	68817	9299.6	65097	55797.5	18599	27899	1859.9	1859.9	5579.8	55797.5
	9299.6	18599	18599	92995.9	0.0	9299.6	1859.9	3719.8	78117	18599.2
	0.0	9299.6	5579.8	9299.6	9299.6	3719.8	148793.4	9299.6	27898.8	111595.1
	1859.9	9299.6	3719.8	9299.6	9299.6	37198	9299.6	52078	9299.6	18599.2
	1859.9	18599	9299.6	9299.6	1859.9	37198	9299.6	31619	0.0	0.0
total volume	301306.7	130194.3	204591.0	238069.5	76256.6	427781.1	197151.3	143213.7	241789.3	427781.1
A **volume X diss conc**	17970413.2	0.0	0.0	2732889.4	0.0	24933370.3	2368626.5	10843321.9	87536007.4	0.0
	5960732.8	17807698.1	10375715.4	12654228.3	0.0	8390893.9	2393880.0	527286.8	0.0	34349322.6
	17483630.7	8333710.9	3860448.4	7159877.9	7184790.9	1698374.1	2670686.4	0.0	2272230.1	12207844.0
	15050640.5	4322949.0	16999893.2	16281767.8	4347855.7	80782545.9	0.0	0.0	1322070.2	14265066.0
	22256798.9	2378415.4	17702003.1	1667161.2	4953847.0	4305954.3	1536596.8	1401448.2	2774248.1	6880141.1
	33038819.6	3004337.9	17654123.0	20420217.3	6687742.1	5873278.5	778553.2	476139.0	3754783.3	28014055.4
	5212879.9	3284073.6	7738363.8	114392160.9	0.0	3023450.2	938507.4	1171748.3	33007837.7	13966322.1
	0.0	3960569.6	1833634.2	3880501.7	2569039.3	1406327.9	59961937.7	3106063.1	5603836.6	159622314.6
	856731.6	5556907.5	1205898.7	1844174.8	3237413.6	9278886.8	4462485.4	16977331.5	5994046.2	5568227.3
	326275.6	10905317.5	3858946.3	1957043.1	710080.9	0.0	3586063.1	14718461.1	0.0	0.0

	sum(A) / Total volume	392.1	457.4	397.0	768.6	389.4	326.6	399.2	343.7	588.4	642.6
B	**Volume X Total Conc**	17947922.9	0.0	0.0	2306971.0	0.0	24065786.4	2369260.6	10556894.6	85853131.8	0.0
		6304732.4	21083995.7	8555119.4	10295633.9	0.0	8334560.8	2398249.3	479858.8	0.0	37042550.0
		17781792.1	9523313.7	3151210.9	6020227.8	7136853.3	1672484.3	2646038.0	0.0	2261744.8	11177463.6
		15602569.6	4901638.4	14201020.5	13788947.7	4260030.2	78221546.7	0.0	0.0	1316096.3	13161398.4
		24249304.8	2941154.8	14735382.8	1369504.5	5466769.9	4271470.1	1554081.3	1393078.6	2552533.5	7505353.2
		34227250.3	3368027.3	14406457.6	16811691.4	6536921.4	5831260.7	833683.8	580294.4	4291843.8	27413685.8
		5455369.3	3574285.7	6363735.5	95363476.9	0.0	2983974.2	968335.2	1264744.2	35966624.9	14137946.4
		0.0	4174818.2	1559870.3	3243340.9	2476447.9	1393573.1	63896919.1	3143261.4	5633829.5	162562858.2
		925599.2	6663518.4	1013223.5	1546887.9	3224002.0	9617148.1	4417139.6	16352399.1	6314855.3	6122729.6
		314755.2	13039000.5	3217935.9	1564431.9	648513.1	11604850.1	3560309.3	14038661.1	0.0	0.0
	sum(B) / Total volume	407.6	532.0	328.5	639.8	390.1	346.0	419.2	333.8	596.3	652.5
C	**Vol x sus conc**	0.0	0.0	0.0	0.0	0.0	0.0	634.1	0.0	0.0	0.0
		343999.6	3276297.6	0.0	0.0	0.0	0.0	4369.3	0.0	0.0	2693227.4
		298161.4	1189602.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		551929.1	578689.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		1992505.9	562739.4	0.0	0.0	512922.8	0.0	17484.5	0.0	0.0	625212.1
		1188430.7	363689.4	0.0	0.0	0.0	0.0	55130.5	104155.4	537060.5	0.0
		242489.4	290212.1	0.0	0.0	0.0	0.0	29827.7	92995.9	2958787.2	171624.3
		0.0	214248.6	0.0	0.0	0.0	0.0	3934981.4	37198.4	29992.9	2940543.6
		68867.5	1106610.9	0.0	0.0	0.0	338261.3	0.0	0.0	320809.1	554502.2
		0.0	2133683.0	0.0	0.0	0.0	11604850.1	0.0	0.0	0.0	0.0
	EMC = Sum (C)/ Total Vol	15.6	74.6	0.0	0.0	6.7	27.9	20.5	1.6	15.9	16.3

B2 – Masses

Mass = concentration x precipitation x area

Mass of As in µg

Sample num.	Sampling day									
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
1	0.52	2.0	0.28	0.22	1.07	0.2	0.20	0.19	0.369	1.04
2	0.46	2.1	0.27	0.28	0.78	0.2	0.20	0.11	0.263	0.56
3	0.35	1.0	0.20	0.40	0.40	0.2	0.20	0.18	0.238	0.14
4	0.32	0.5	0.33	0.40	0.31	0.2	0.20	0.22	0.294	0.18
5	0.31	0.5	0.19	0.23	0.26	0.2	0.20	0.22	0.401	0.31
6	0.40	0.5	0.20	0.15	0.10	0.2	0.20	0.17	0.415	0.18
7	0.41	0.5	0.28	0.27	0.25	0.2	0.20	0.15	0.456	0.34
8	0.46	0.5	0.13	0.23	0.22	0.2	0.20	0.39	0.206	0.49
9	0.27	0.5	0.15	0.24	0.20	0.2	0.20	0.18	0.283	0.18
10	0.11	0.5	0.18	0.16	0.17	0.2	0.20	0.27		

Mass of Cd in µg

Sample num	Sampling day									
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
1	0.79	8.83	12.27	3.51	2.26	8.37	1.15	1.23	9.49	0.00
2	0.23	7.24	8.92	7.72	3.72	0.93	8.01	0.06	0.27	5.97
3	0.23	7.20	14.14	2.09	2.84	4.09	0.76	0.00	0.25	0.64
4	0.34	20.25	49.12	1.99	1.35	1.30	0.00	0.11	0.16	1.11
5	0.38	12.11	22.16	0.64	1.59	16.37	1.57	0.13	0.34	1.21
6	0.52	1.14	30.03	12.81	0.46	3.35	0.85	0.15	0.61	3.01
7	0.00	5.68	1.76	34.32	0.39	5.06	0.03	0.19	160.70	1.59
8	5.17	2.36	0.00	3.12	0.67	4.06	14.58	1.34	2.11	35.76
9	1.71	3.86	0.78	2.88	0.15	1.16	7.90	0.89	0.86	21.45
10	0.46	1.59	0.74	1.26	0.70	9.63	0.93	0.95	0.00	0.00

Mass of Cu in mg

Sample num	Sampling day									
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
1	0.03	0.39	0.67	0.16	0.13	0.09	0.01	0.18	0.45	0.00
2	0.02	0.40	0.11	0.84	0.25	0.00	0.05	0.00	0.01	0.44
3	0.02	0.56	0.34	0.07	0.14	0.01	0.01	0.00	0.01	0.10
4	0.02	0.37	1.98	0.07	0.08	0.00	0.00	0.01	0.01	0.05
5	0.10	1.65	0.68	0.02	0.04	0.13	0.02	0.01	0.02	0.07
6	0.04	0.07	0.49	0.54	0.08	0.01	0.01	0.01	0.03	0.08
7	0.00	0.63	0.06	3.10	0.03	0.01	0.00	0.02	1.34	0.07
8	0.30	0.09	0.00	0.12	0.14	0.01	0.04	0.08	0.08	0.73
9	0.08	0.12	0.03	0.12	0.04	0.01	0.04	0.04	0.07	0.05
10	0.03	0.15	0.08	0.05	0.02	0.05	0.01	0.07	0.00	0.00

Mass of Pb in mg

Sample num	Sampling day									
	1st	2nd	3rd	4th	5th	6^{th}	7th	8th	9th	10th
1	0.02	0.20	0.13	0.10	0.14	0.06	0.00	0.19	0.60	0.00
2	0.01	0.38	0.08	0.15	0.19	0.01	0.00	0.01	0.03	1.97
3	0.01	0.14	0.16	0.02	0.08	0.01	0.00	0.00	0.01	0.27
4	0.01	0.24	0.20	0.03	0.06	0.00	0.00	0.00	0.01	0.13
5	0.00	0.23	0.18	0.01	0.03	1.55	0.00	0.01	0.03	0.60
6	0.01	0.02	0.23	0.11	0.03	0.04	0.00	0.01	0.02	0.21
7	0.00	0.04	0.03	0.36	0.02	0.04	0.00	0.03	2.34	0.10
8	0.08	0.02	0.00	0.03	0.04	0.00	0.06	0.28	0.44	35.56
9	0.08	0.01	0.01	0.04	0.01	0.00	0.02	0.04	0.03	0.37
10	0.01	0.01	0.01	0.05	0.06	0.02	0.00	0.04	0.00	0.00

Mass of Zn in mg

Sample num	Sampling day									
	1st	2nd	3rd	4th	5th	6^{th}	7th	8th	9th	10th
1	1.79	28.30	15.37	4.61	13.10	24.07	2.37	10.56	82.99	0.00
2	1.33	21.08	8.13	8.24	20.20	2.78	4.32	0.48	2.11	37.04
3	1.21	9.52	18.59	3.01	7.14	8.36	2.65	0.00	2.26	11.18
4	2.12	12.25	27.93	3.45	6.82	1.78	0.00	0.94	1.32	13.16
5	3.29	17.65	17.39	0.68	3.12	20.88	1.55	1.39	2.55	7.51
6	3.70	3.37	15.23	16.81	2.61	7.00	0.83	1.16	4.29	27.41
7	0.00	3.57	3.18	95.36	3.28	8.95	0.97	3.16	35.97	14.14
8	35.20	4.17	0.00	3.24	1.98	3.48	33.95	7.54	5.63	162.56
9	9.26	3.33	0.51	1.55	0.64	0.96	37.55	9.34	6.31	6.12
10	3.15	3.26	0.64	1.56	3.24	11.60	3.56	14.04	0.00	0.00

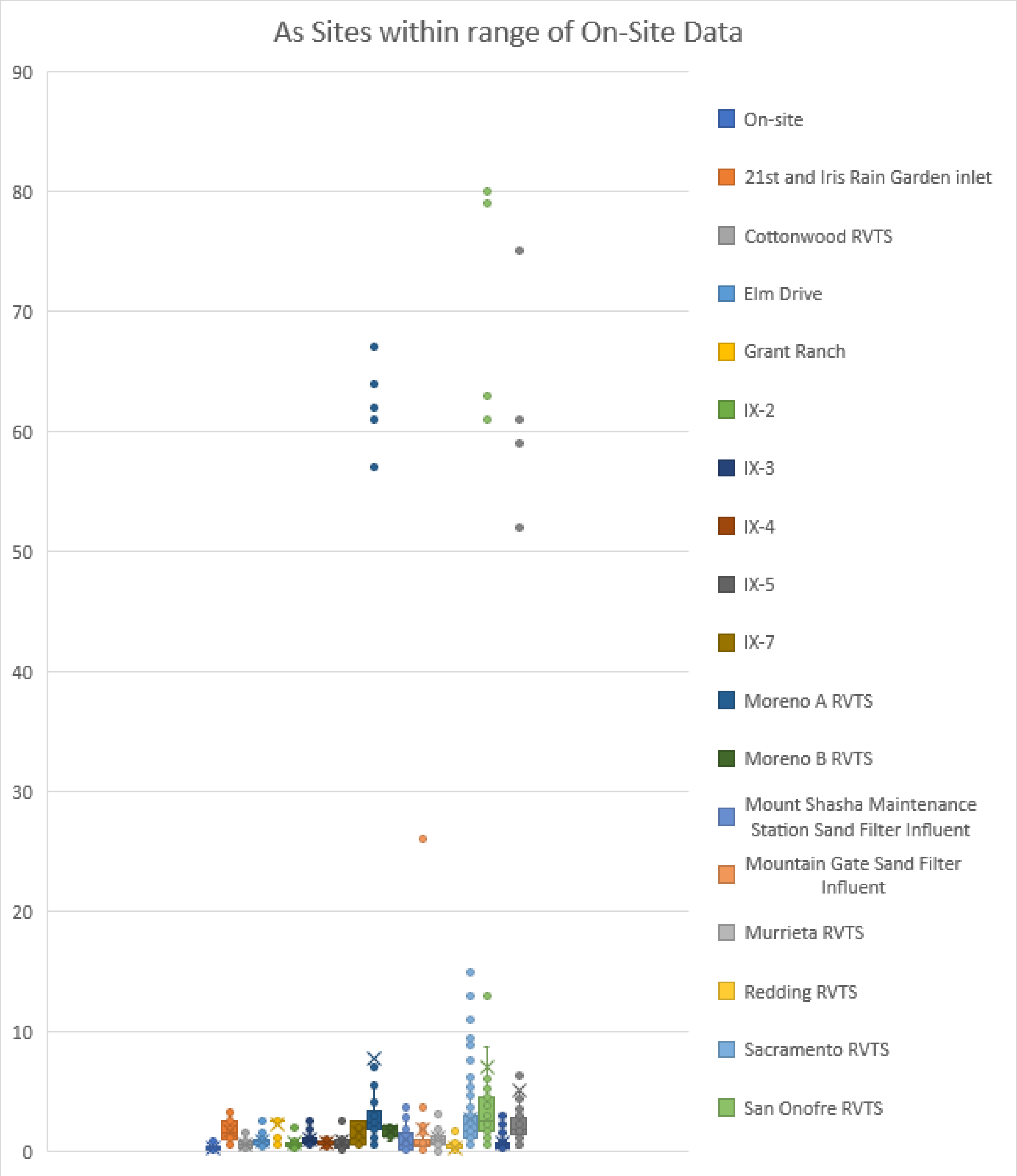
B3 – Statistics

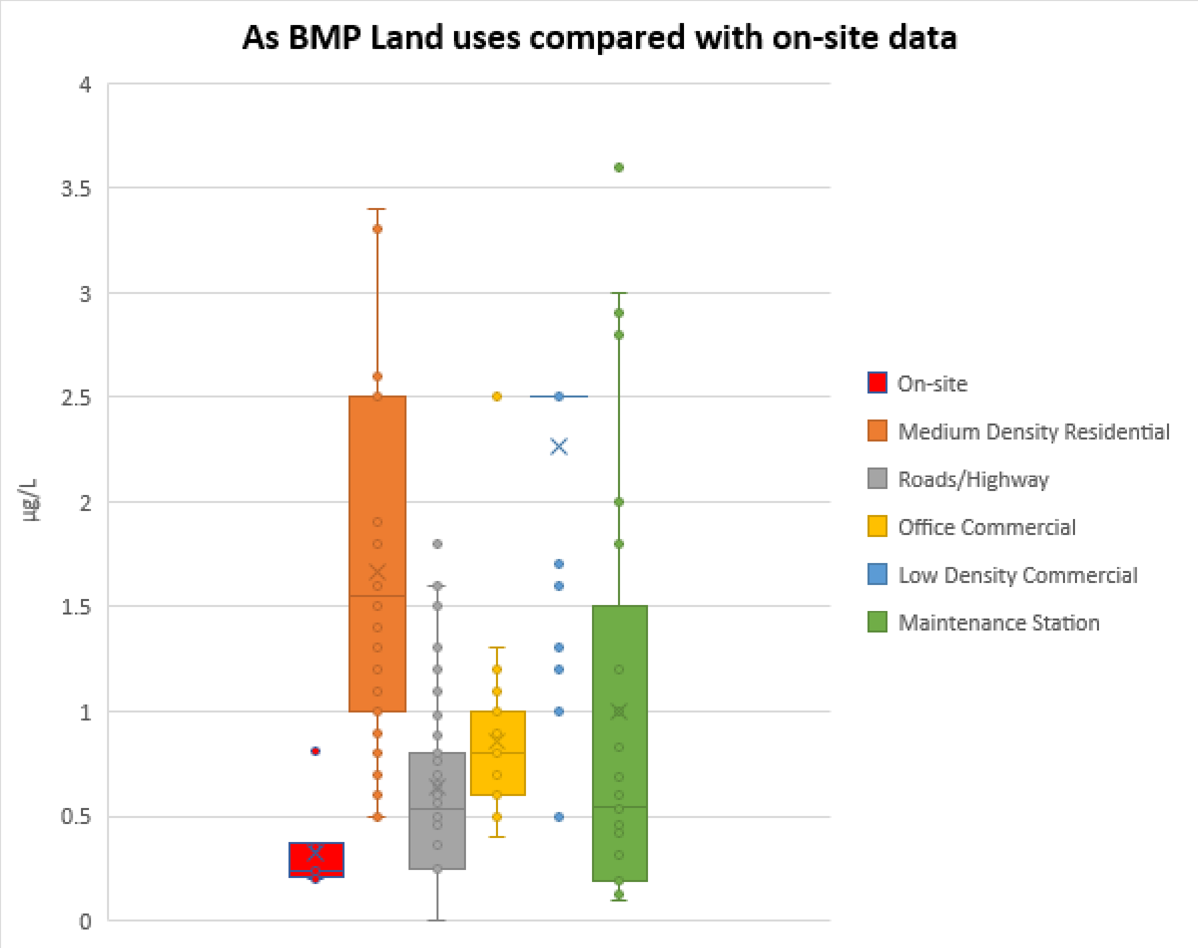
	1st		2nd		3rd		4th		5th		6th		7th		8th		9th		10th		
	F	UF	F	UF	F	UF	F	UF	F	UF	F	UF	F	UF	F	UF	F	UF	F	UF	
As & Cd	0.70	-0.18	0.30	0.16	0.31	0.54	0.12	0.96	0.83	0.92	-	-	-	-	0.51	0.55	0.76	0.57	-0.18	-0.10	0.42
As & Cu	0.43	0.24	0.77	0.04	0.14	0.07	-0.06	0.43	0.98	0.52	-	-	-	-	0.73	0.55	0.64	0.62	0.95	0.98	0.50
As & Pb	0.49	0.38	0.98	0.93	0.44	0.35	0.05	0.37	0.92	0.94	-	-	-	-	0.46	0.72	-0.05	0.37	-0.02	0.20	0.47
As & Zn	0.66	0.65	0.93	0.87	0.75	0.81	0.88	0.76	0.96	0.97	-	-	-	-	0.39	0.23	0.69	0.42	0.69	0.80	0.72
Cd & Cu	0.40	-0.31	0.28	0.19	0.09	0.48	0.26	0.42	0.88	0.45	-0.30	0.53	0.10	0.26	0.26	0.43	0.65	0.95	-0.17	0.00	0.29
Cd & Pb	0.84	0.74	0.21	0.11	0.04	0.35	-0.21	0.14	0.85	0.89	-0.20	-0.43	-0.08	-0.46	0.48	0.41	0.25	0.89	0.13	0.13	0.25
Cd & Zn	0.49	-0.08	0.04	0.38	0.32	0.61	0.14	0.77	0.90	0.90	0.23	0.60	-0.54	-0.65	0.65	0.71	0.46	-0.29	-0.05	0.00	0.28
Cu & Pb	0.20	-0.02	0.73	0.00	0.67	0.18	0.24	0.20	0.95	0.58	-0.05	-0.16	-0.06	-0.15	0.43	0.56	0.22	0.79	0.03	0.30	0.28
Cu & Zn	0.37	0.39	0.69	0.06	-0.35	0.35	-0.26	0.54	0.99	0.53	0.32	0.00	0.06	-0.09	0.11	0.10	0.11	-0.14	0.68	0.87	0.27
Pb & Zn	0.35	0.29	0.91	0.68	0.22	0.53	-0.07	0.09	0.98	0.98	-0.63	-0.68	0.39	0.55	-0.10	-0.14	-0.59	-0.64	0.61	0.60	0.22

F = Filtered; UF = Unfiltered; As & Cd = regression between As and Cd for all the storm events

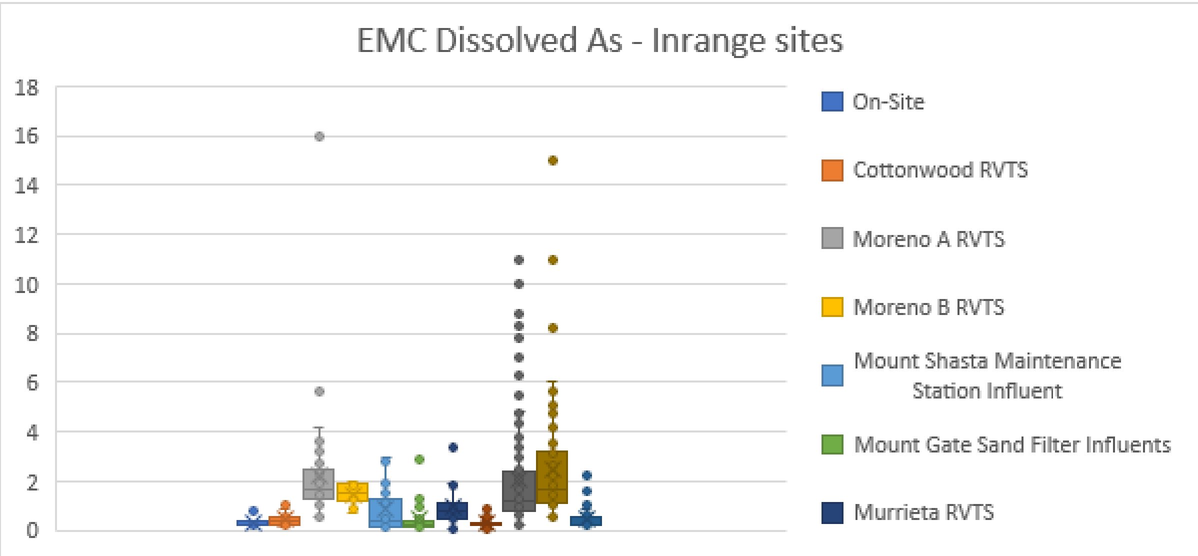
Appendix C: Graphs

C1 – Arsenic

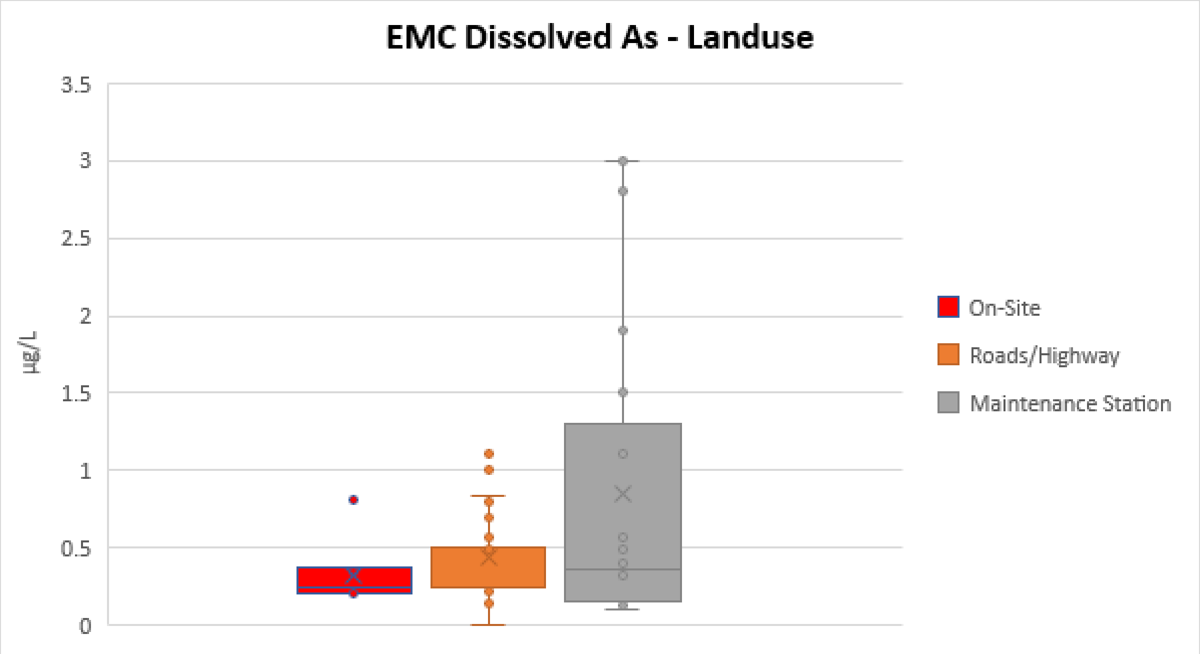




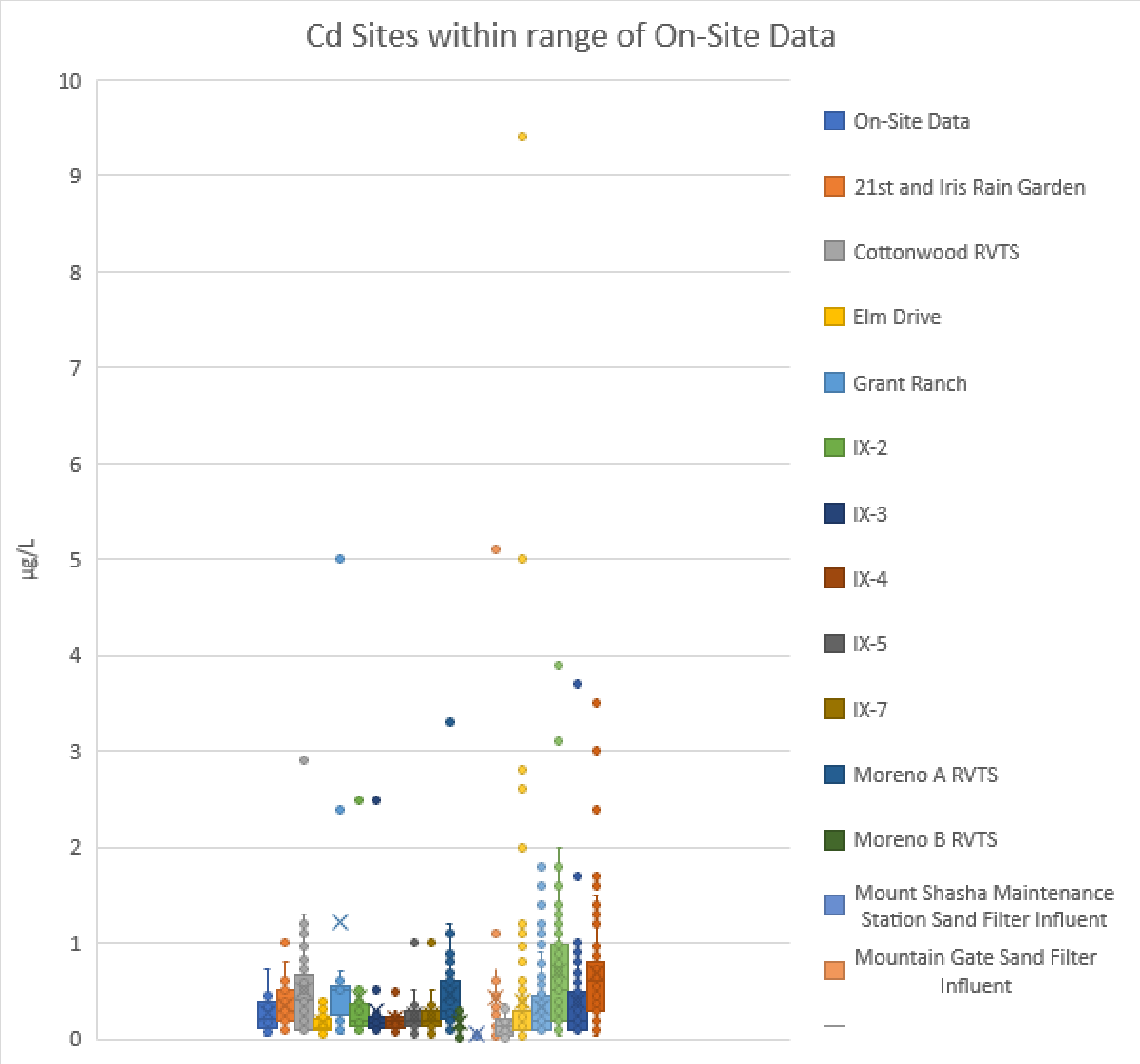
As BMP Land uses compared with on-site data
µg/L
0
0.5
1
1.5
2
2.5
3
3.5
4
On-site
Medium Density Residential
Roads/Highway
Office Commercial
Low Density Commercial
Maintenance Station



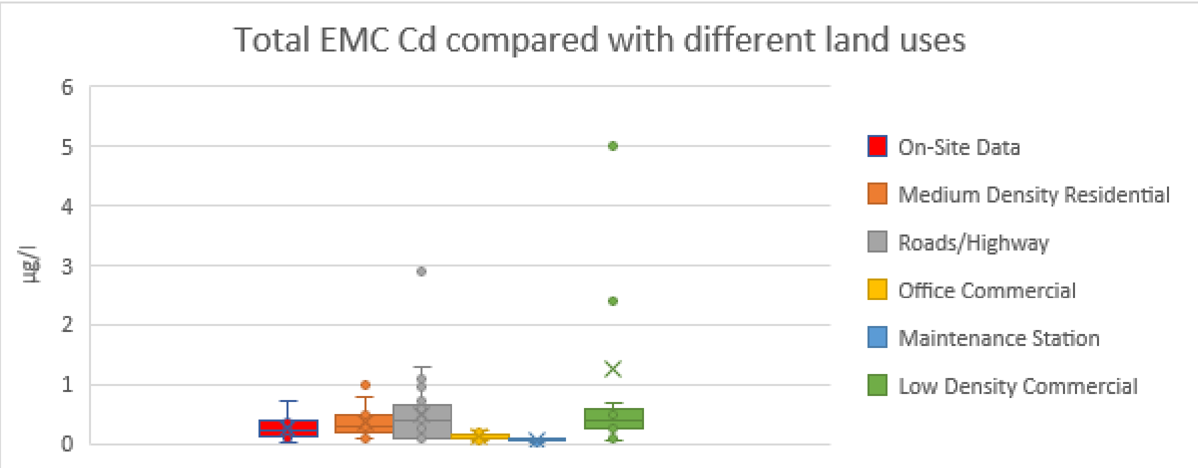
EMC Dissolved As - Inrange sites
0
2
4
6
8
10
12
14
16
18
On-Site
Cottonwood RVTS
Moreno A RVTS
Moreno B RVTS
Mount Shasta Maintenance Station Influent
Mount Gate Sand Filter Influents
Murrieta RVTS


EMC Dissolved As - Landuse
3.5
3
2.5
2
1.5
1
0.5
0
µg/L
On-Site
Roads/Highway
Maintenance Station

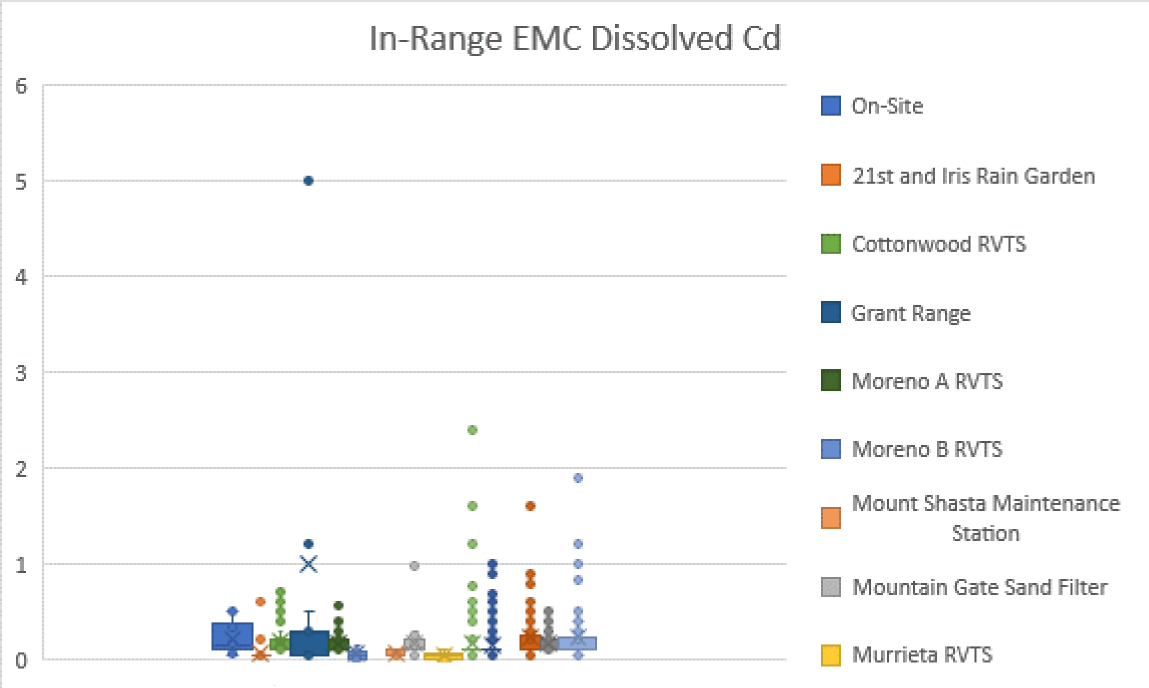
Cadmium

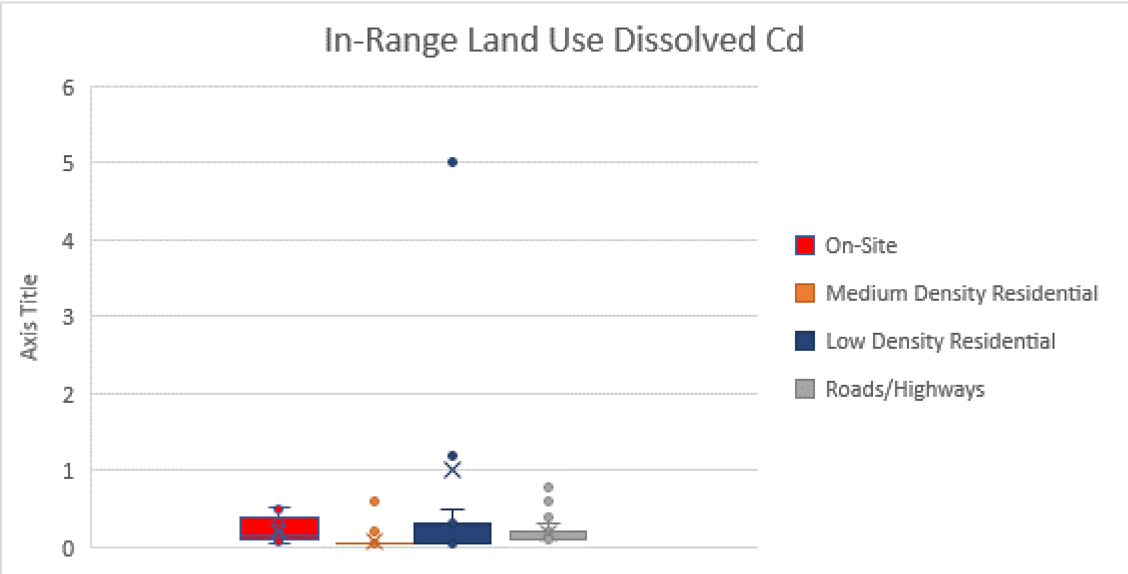


Cd Sites within range of On-Site Data
μg/L
10
9
8
7
6
5
4
3
2
1
0
On-Site Data
21st and Iris Rain Garden
Cottonwood RVTS
Elm Drive
Grant Ranch
IX-2
IX-3
IX-4
IX-5
IX-7
Moreno A RVTS
Moreno B RVTS
Mount Shasha Maintenance Station Sand Filter Influent
Mountain Gate Sand Filter Influent

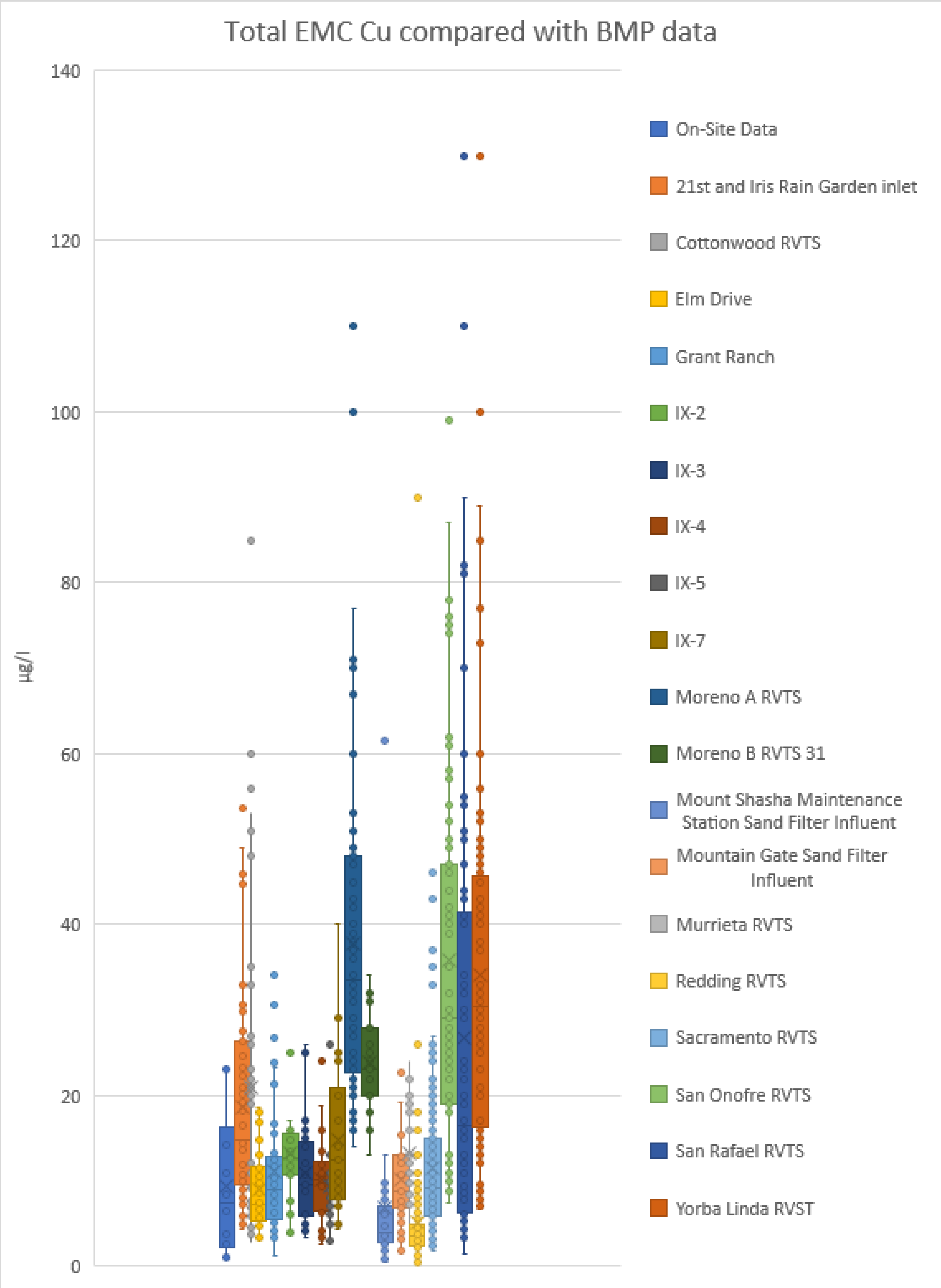


Total EMC Cd compared with different land uses
μg/l
6
5
4
3
2
1
0
On-Site Data
Medium Density Residential
Roads/Highway
Office Commercial
Maintenance Station
Low Density Commercial

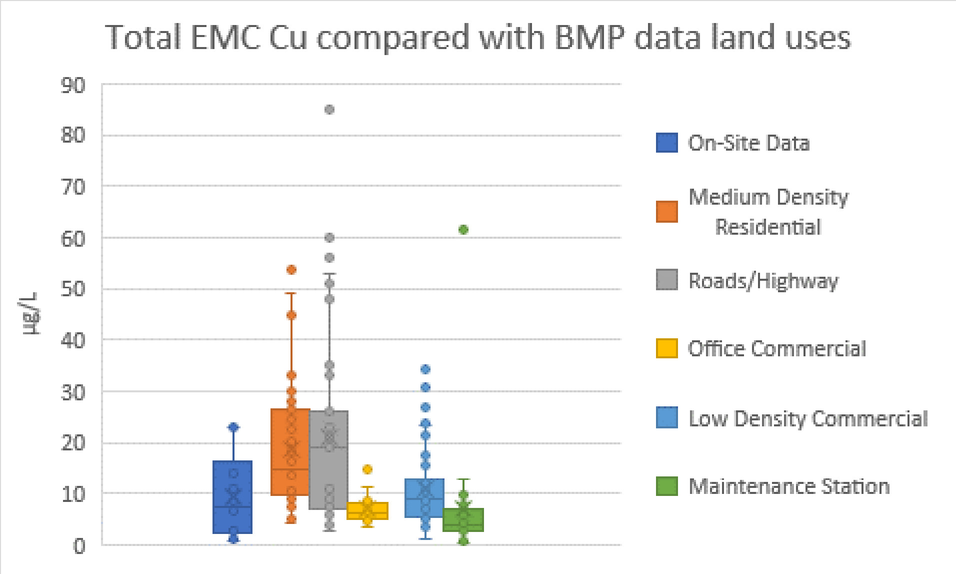

In-Range EMC Dissolved Cd
6
5
4
3
2
1
0
On-Site
21st and Iris Rain Garden
Cottonwood RVTS
Grant Range
Moreno A RVTS
Moreno B RVTS
Mount Shasta Maintenance Station
Mountain Gate Sand Filter
Murrieta RVTS

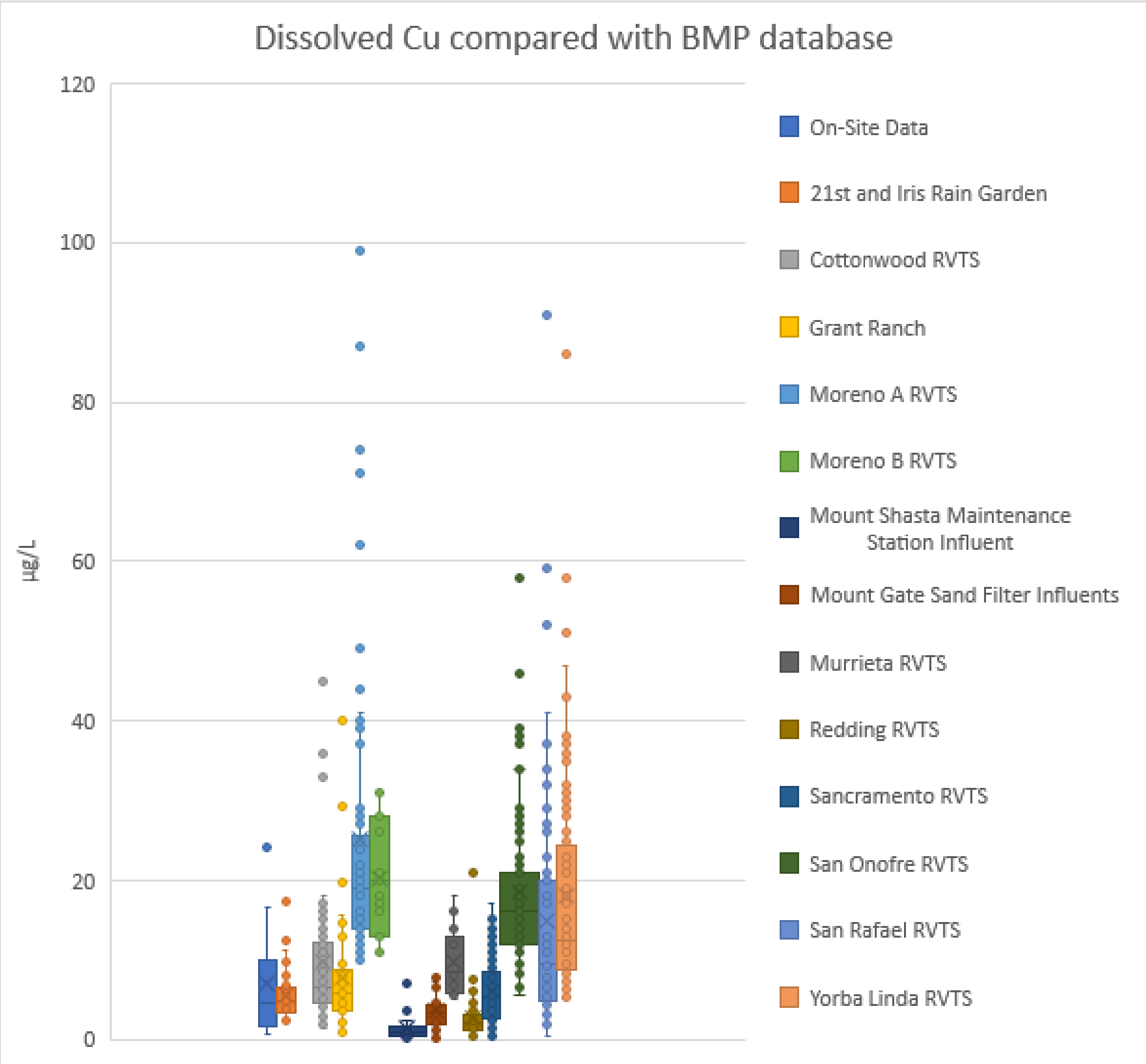

In-Range Land Use Dissolved Cd
Axis Title
6
5
4
3
2
1
0
On-Site
Medium Density Residential
Low Density Residential
Roads/Highways

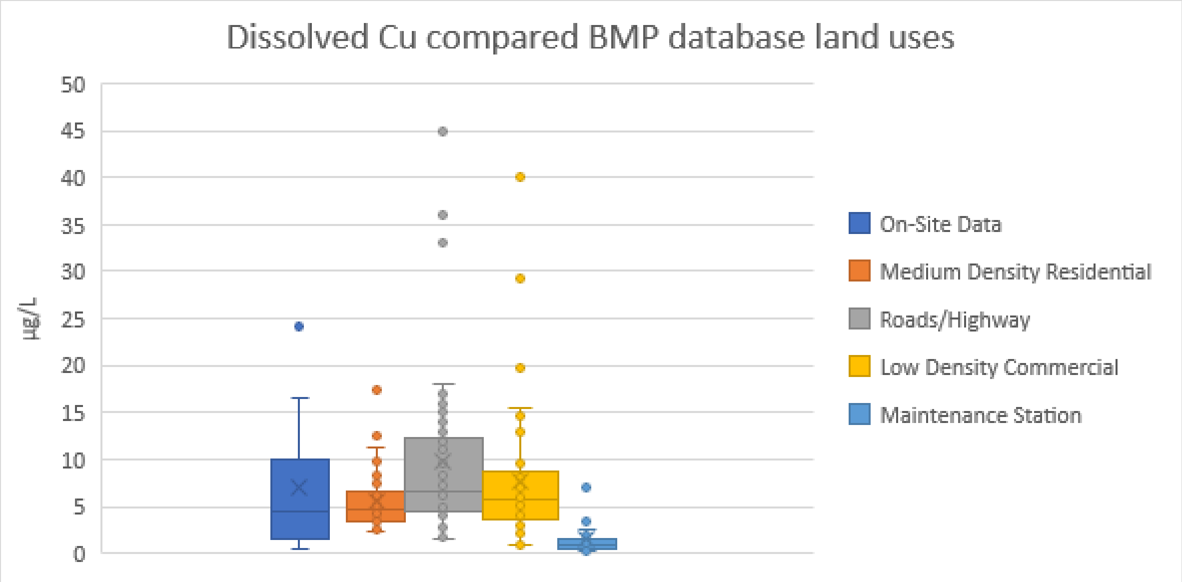
Copper



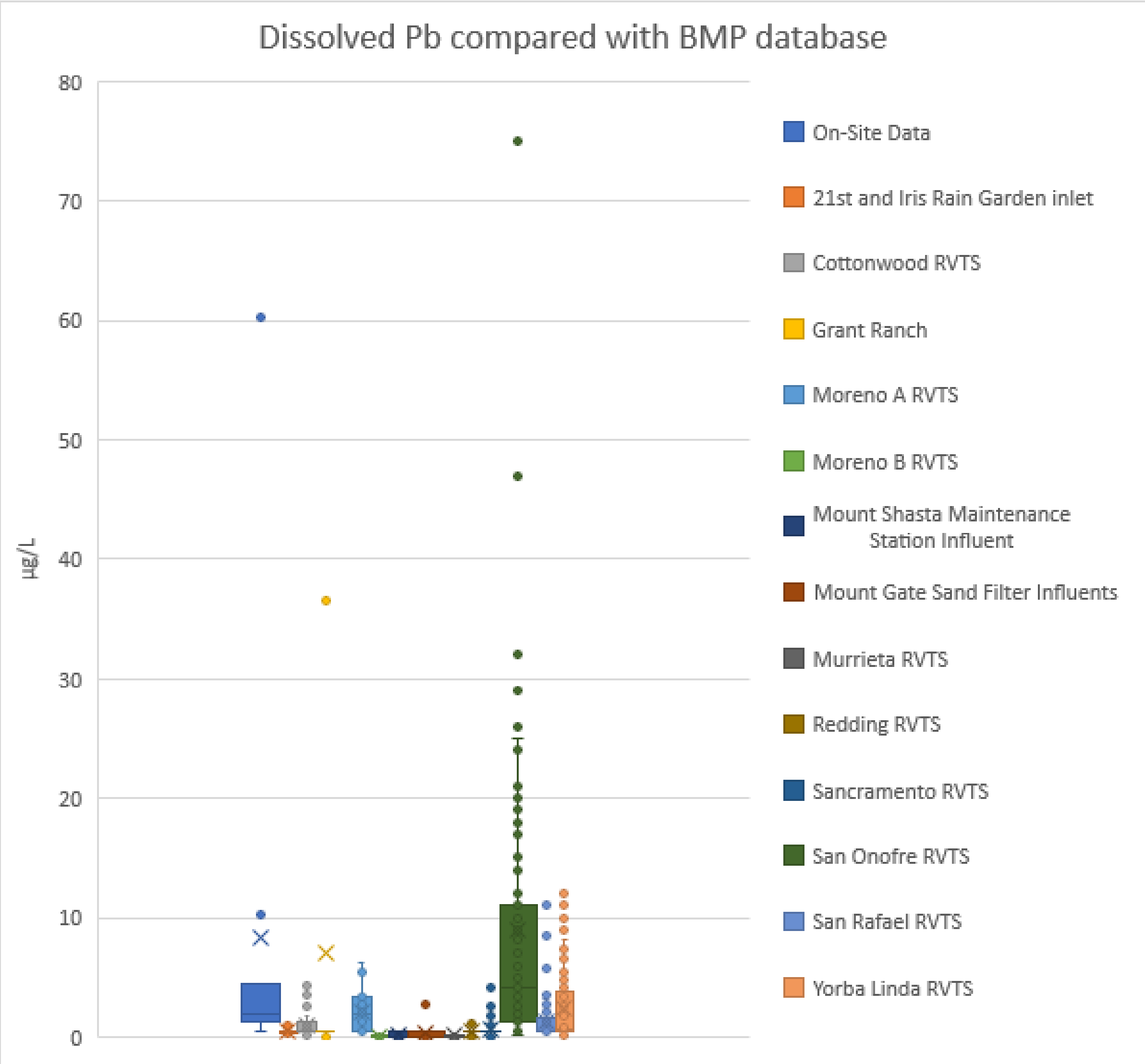
Total EMC Cu compared with BMP data
µg/l
140
120
100
80
60
40
20
0
On-Site Data
21st and Iris Rain Garden inlet
Cottonwood RVTS
Elm Drive
Grant Ranch
IX-2
IX-3
IX-4
IX-5
IX-7
Moreno A RVTS
Moreno B RVTS 31
Mount Shasha Maintenance Station Sand Filter Influent
Mountain Gate Sand Filter Influent
Murrieta RVTS
Redding RVTS
Sacramento RVTS
San Onofre RVTS
San Rafael RVTS
Yorba Linda RVST

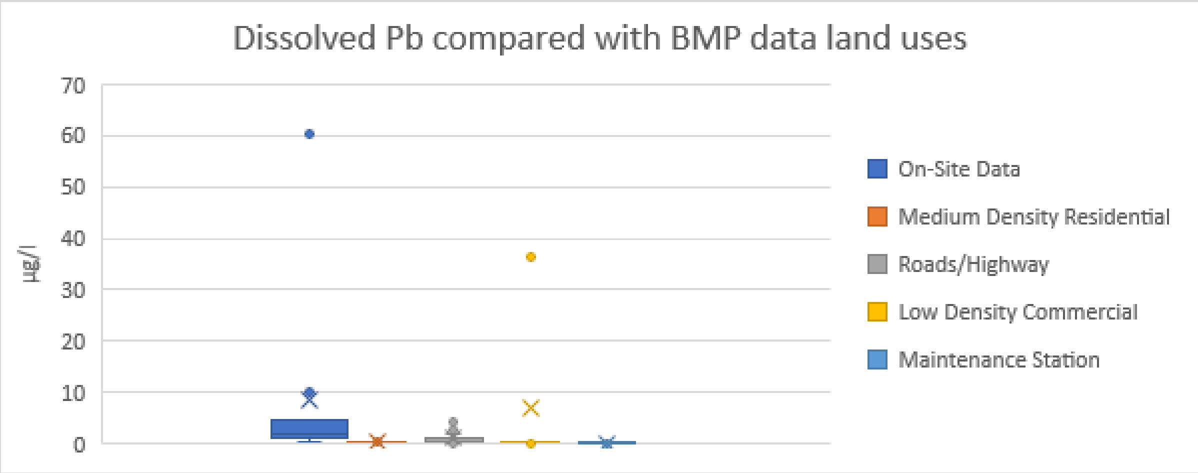

Total EMC Cu compared with BMP data land uses
90
80
70
60
50
40
30
20
10
0
µg/L
On-Site Data
Medium Density Residential
Roads/Highway
Office Commercial
Low Density Commercial
Maintenance Station


Dissolved Cu compared with BMP database
120
100
80
60
40
20
0
µg/L
On-Site Data
21st and Iris Rain Garden
Cottonwood RVTS
Grant Ranch
Moreno A RVTS
Moreno B RVTS
Mount Shasta Maintenance Station Influent
Mount Gate Sand Filter Influents
Murrieta RVTS
Redding RVTS
Sancramento RVTS
San Onofre RVTS
San Rafael RVTS
Yorba Linda RVTS

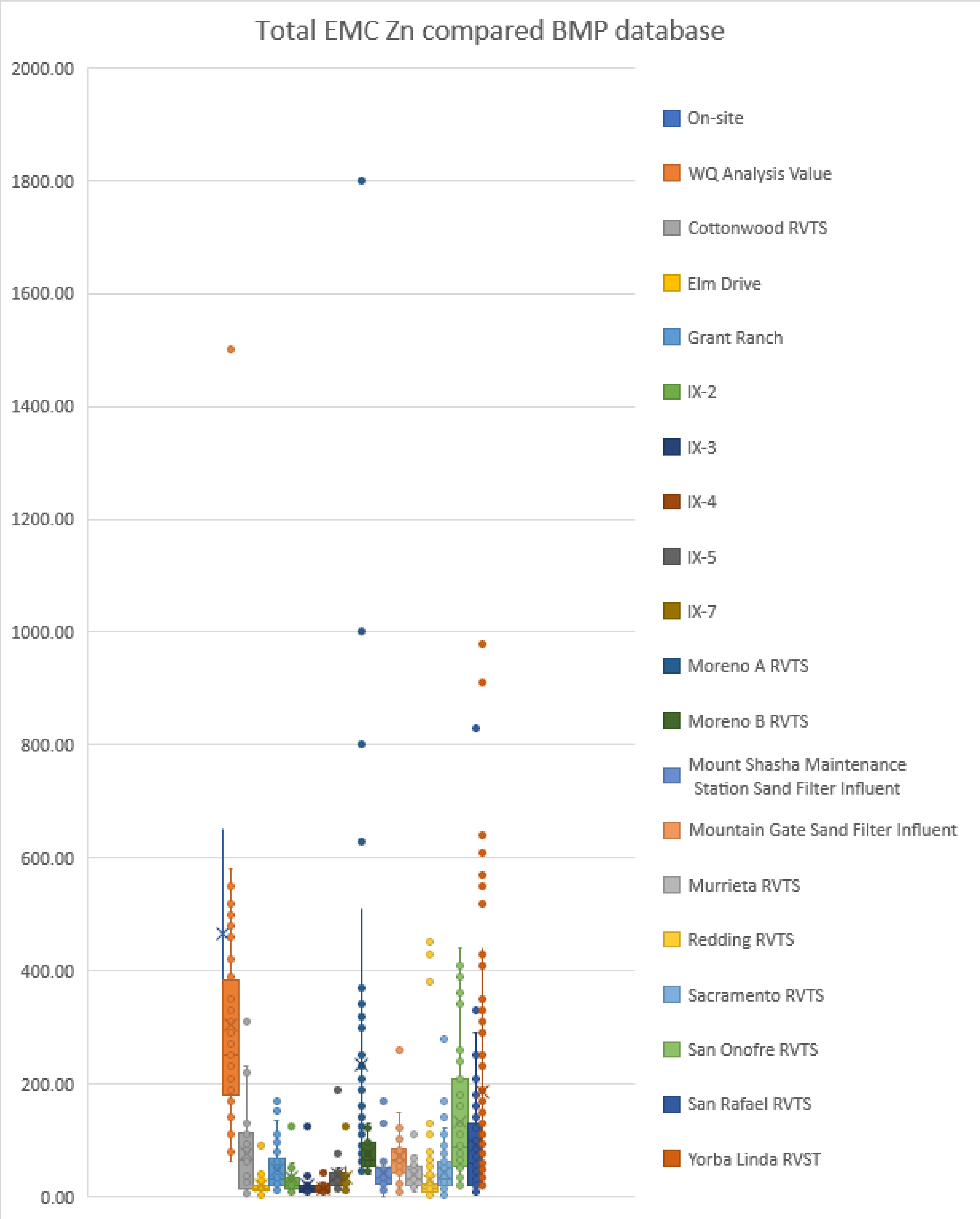

Dissolved Cu compared BMP database land uses
µg/L
50
45
40
35
30
25
20
15
10
5
0
On-Site Data
Medium Density Residential
Roads/Highway
Low Density Commercial
Maintenance Station

Lead

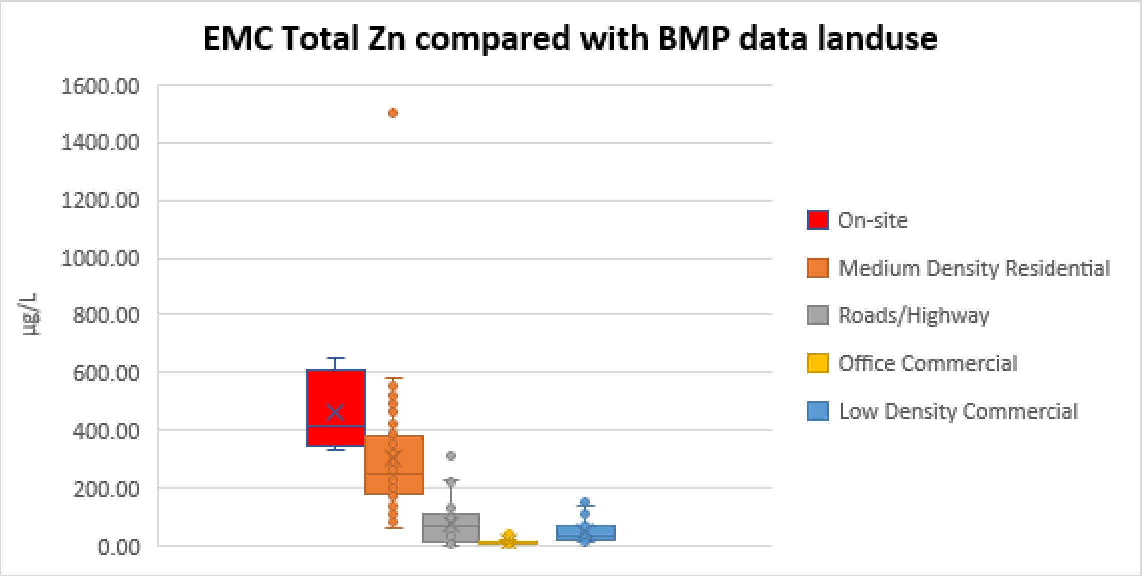

Dissolved Pb compared with BMP database
µg/L
80
70
60
50
40
30
20
10
0
On-Site Data
21st and Iris Rain Garden inlet
Cottonwood RVTS
Grant Ranch
Moreno A RVTS
Moreno B RVTS
Mount Shasta Maintenance Station Influent
Mount Gate Sand Filter Influents
Murrieta RVTS
Redding RVTS
Sancramento RVTS
San Onofre RVTS
San Rafael RVTS
Yorba Linda RVTS


Dissolved Pb compared with BMP data land uses
µg/l
70
60
50
40
30
20
10
0
On-Site Data
Medium Density Residential
Roads/Highway
Low Density Commercial
Maintenance Station

Zinc



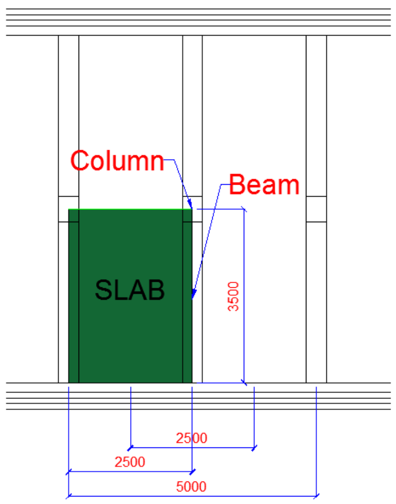
Total EMC Zn compared BMP database
2000.00
1800.00
1600.00
1400.00
1200.00
1000.00
800.00
600.00
400.00
200.00
0.00
On-site
WQ Analysis Value
Cottonwood RVTS
Elm Drive
Grant Ranch
IX-2
IX-3
IX-4
IX-5
IX-7
Moreno A RVTS
Moreno B RVTS
Mount Shasha Maintenance Station Sand Filter Influent
Mountain Gate Sand Filter Influent
Murrieta RVTS
Redding RVTS
Sacramento RVTS
San Onofre RVTS
San Rafael RVTS
Yorba Linda RVST



EMC Total Zn compared with BMP data landuse
µg/L
1600.00
1400.00
1200.00
1000.00
800.00
600.00
400.00
200.00
0.00
On-site
Medium Density Residential
Roads/Highway
Office Commercial
Low Density Commercial

Appendix D: Preliminary Design

D1 – Slab, Beam, Columns and Retaining wall Calculations and Layouts



Slab layout dimensions for calculations	
LL = 5kN/m^2	SANS 1062
h_{slab} = 200mm (variations of loads is unpredictable, ensuring that the slab can withstand any load, a thick slab is recommended)	
Concrete density = 25 kN/m^3	SANS0100-1 pg. 10
DL = 25 x 0.2 = 5 kN/m^2	
l_{ex} = 2500mm l_{ey} = 3500mm l_{ex}/ l_{ey} = 1.4	
Table 15: Case 4: two adjacent edges discontinuous	
M_x (-) : $\beta_{x(-)}$ = 0.074 M_x (+): $\beta_{x(+)}$ = 0.055 M_y (-) : $\beta_{y(-)}$ = 0.045 M_y (+): $\beta_{y(+)}$ = 0.034	SANS 0100-1
n = 1.2DL + 1.6LL = 9.25 kN/m^2	SANS 0100-1 pg.17
M = $\beta n l^2$	SANS 0100-1 pg.44
M_x (-) = 0.074 x 9.25 x 2.5^2 = - 4.28 kN/m^2 M_x (+)= 0.055 x 9.25 x 2.5^2 = 3.18kN/m^2 M_y (-) = 0.045 x 9.25 x 3.5^2 = -5.10kN/m^2 M_y (+)= 0.034 x 9.25 x 3.5^2 = 3.85kN/m^2	
$K = \frac{M}{bd^2 f_{cu}} = \frac{5.1x10^6}{1000.180^2.30} = 0.0052 < 0.95$	SANS 0100-1 pg. 24
$A_s = \frac{M}{0.87 f_y z} = \frac{5.1x10^6}{0.87x450x0.95x200} = 68.56mm^2/m$	
$A_{s,min} = \frac{0.13bh}{100} = \frac{0.13x1000x200}{100} = 260mm^2/m$	SANS 0100-1 pg. 27
3Y12 @ 350 in the x – and y-direction	

Beam Reinforcement and Design calculations

Beams: 400 x 400mm

SANS0100 – 1

DL_{Slab} = 0.25 x 2.5 x 25 = 15.625 kNm/m
DL_{Beam} = 0.4 x 0.4 x 25 = 4 kNm/m
LL_{Slab} = 5 x 2.5 = 12.5 kNm/m
LL_{Beam} = 5kNm/m
n = 1.2DL + 1.6LL
= 1.2 x (19.625) + 1.6 x (17.5)
= 123.55 kNm/m

LL/DL = 0.89 use Table 4: SANS 0100-1 — SANS 0100-1

M = wl/14(At middle of interior spans)
= $nl^2/14$
= 123.55 x $3.5^2/14$
= 108.106 kNm

M = - wl/9(At middle of interior spans)
= - $nl^2/9$
= - 123.55 x $5^2/9$
= - 343.194 kNm, where Prokon gave -372.7kNm @3.5m
Therefore, the highest value would be used = -372.2kNm — SANS 0100-1 pg.24

b = 400mm
d = 400mm

K ≤ K'
K' = 0.156
K = $M / bd^2 f_{cu}$
= 108.106 $x10^6$/ (400 x $(400-50)^2$ x 30)
= 0.0735 < K' no compression reinforcement required for middle span
K ≤ K'
K' = 0.156
K = $M / bd^2 f_{cu}$
= 372.2 $x10^6$/ (400 x $(400-50)^2$ x 30)
= 0.253 > K' compression reinforcement required @ support

Required area of reinforcement (middle span)

$$A_S' = \frac{M}{0.87 f_y z}$$

= 108.106 x 10^6/ (0.87 x 450 x 380)
= 726.66 mm^2

z = d (0.5 +√(0.25 – k/0.9)) ≤ 0.95d
= 400(0.5 +√(0.25 – 0.0116/0.9))
= 400
z = 0.95d = 380mm

2Y25 = 981.75mm^2

Compression reinforcement $f_{yc} = \frac{f_y}{\gamma_m + f_y/2000}$ = 450/(1.15+450/2000) = 327.27MPa $A'_s = \frac{(K-K')f_{cu}bd^2}{f_{yc}(d-d')}$ = (0.253-0.156) x 30 x 400 x 400^2/327.27(350-50) = 1896.905mm^2 3Y32 = 2412.74mm^2 $A_s = \frac{K'f_{cu}bd^2}{0.87f_yz} + \frac{A'_sf_{yc}}{0.87f_y}$ =0.156 x 30 x 400 x 400^2/(0.87 x 450 x 380) + 1896.905x327.27/(0.87x450) = 3599.018 mm^2 3Y40 = 3769.9mm^2	

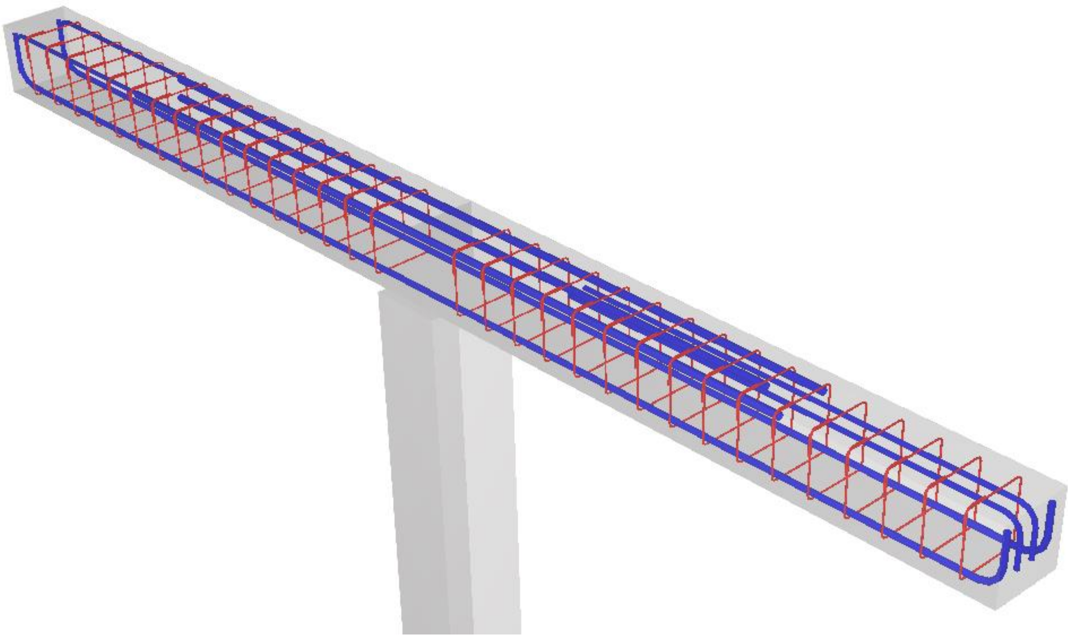


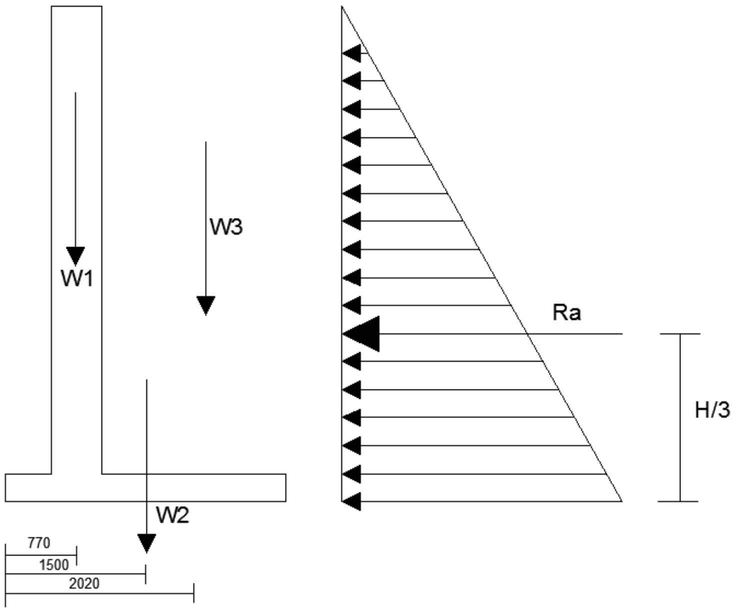
Figure D – 1: Prokon 3D image of reinforcement the beams

Column Reinforcement and Design Calculations	Codes
Columns characteristics Axial force N_u = -213kN Moment M_u = -372.7kNm Concrete strength: f_{cu} = 30MPa Ultimate strain: ε_{cu} = 0.0035 Reinforcement material Characteristic strength f_y = 450 MPa Modulus of elasticity E_s = 200 GPa Section Dimensions: Height h = 500 mm Width b = 400 mm Reinforcement position c = 50mm Reinforcement depths Compression d' = c = 50mm Tension d = h – c = 450mm Design Yield strain in tension $\varepsilon_y = -\frac{0.87\,f_y}{E_s}$ = -1.957×10^{-3} Yield stress and strain in compression $f_{yc} = \frac{f_y}{1.15+\frac{f_y}{2000}}$ = 327.3MPa $\varepsilon_{yc} = \frac{f_{yc}}{E_s} = 1.3636x10^{-3}$ $f_{yc.mod} = f_{yc} - 0.45 f_{cu} = 313.8\ MPa$ Neutral axis depth x = 200mm Depth of stress block s = 0.9x = 180mm **Slenderness:** End fixity and bracing for bending about the X-X axis: The column is unbraced, therefore β_x = 1.3 End fixity and bracing for bending about the Y-Y axis: The column is braced, therefore β_y = 0.75 Effective column height: l_{ex} = β_x L_0 = 1.3 x 5 = 6.5m l_{ey} = β_y L_0 = 0.75 x 5 = 3.75m Column slenderness about both axis: λ_x = l_{ex}/h = 6.5/0.5 = 13 > 10 λ_y = l_{ey}/h = 3.75/0.4 = 9.375 < 15 - Column is slender Check slenderness limit: L_0 = 5m < 60 b' = 24m b' = b – d'_y = 0.4 – 0.05 = 0.35 - Slenderness limit not exceeded **Minimum moments for design:** e_{minx} = 0.05 x h = 0.05 x 0.5 = 0.025m e_{miny} = 0.05 x b = 0.05 x 0.4 = 0.02m M_{min} = e_{min} x N = 0.02 x -213 = -4.26 kNm Initial moments *The initial end moments about the X-X axis:* M_1 = Smaller initial end moment = 0.0 kNm M_2 = Larger initial end moment = 0.0 kNm The initial moment near mid-height of the column:	

M_i = -0.4M_1 +0.6M_2 = 0kNm *The initial end moments about the Y-Y axis:* M_1 = Smaller initial end moment = 0.0 kNm M_2 = Larger initial end moment = 372.7 kNm The initial moment near mid-height of the column: M_i = -0.4M_1 +0.6M_2 = 223.62kNm M_{i2} = 0.4M_2 = 149.08kNm Design ultimate load and moment: N_u = -213kN For bending about the X-X axis, the maximum design moment is the greatest of - M = M_2 + M_{add} = 0 - M = e_{min} x N_u = 0.02 x-213 = -4.26kNm For bending about the Y-Y axis, the maximum design moment is the greatest of - M_2 = 372.7kNm - M = M_i + M_{add} = 223.62 + 0 = 223.62kNm - M = M_1 + M_{add}/2 = 0kNm - M = e_{min} x N_u = 0.02 x-213 = -4.26kNm Reinforcement $A'_s = \frac{1}{f_{yc.mod}(d-d')}[M_u + N_u\left(d-\frac{h}{2}\right) - 0.45f_{cu}bs\left(d-\frac{s}{2}\right)]$ = 6096 mm^2 Reinforcement with design graphs A_{sc} = 6875mm^2 4Y40 & 4Y32 = 8243.54mm^2	

Column Footing calculations	
Column footings Point load = 283 kN Take M = 0 *Soil pressure: P* = $\frac{N}{BD} = \frac{N}{D^2}$ (if B = D) B = D Assuming soil bearing capacity is 143.64kN/m^2 $D = \sqrt{\frac{N}{p}} = \sqrt{\frac{283}{143.64}} = 1.404m$ Column base = 1.5 x 1.5 m	

Retaining wall



Unit weight of soil = 18 kN/m^3

$K_a = \frac{1-sin\varphi}{1+sin\varphi} = \frac{1-sin35°}{1+sin35°} = 0.271$

$\omega_1 = 0.54 \; x \; 5 \; x \; 25 = 67.5$

$\omega_2 = 0.3 \; x \; 3 \; x \; 25 = 22.5$

$\omega_3 = 1.96 \; x \; 5 \; x \; 18 = 176.4$

$\sum \omega = 266.4$

$M_1 = 67.5 \; x \; 0.77 = 51.975$

$M_2 = 22.5 \; x \; 1.5 = 33.7$

$M_3 = 176.4 \; x \; 2.02 = 356.328$

$\sum M = 442.003$

$R_a = P_a \frac{H}{2}$

$P_a = P_v K_a - 2c\sqrt{K_a}$ [c = 0: cohesionless soil]

$P_v = \gamma H$

$P_a = \gamma H K_a$

$R_a = \frac{\gamma H K_a H}{2} = \frac{\gamma K_a H^2}{2} = \frac{18 \; x \; 0.271 \; x \; 5.3 \; x \; 5.3}{2} = 68.51151$

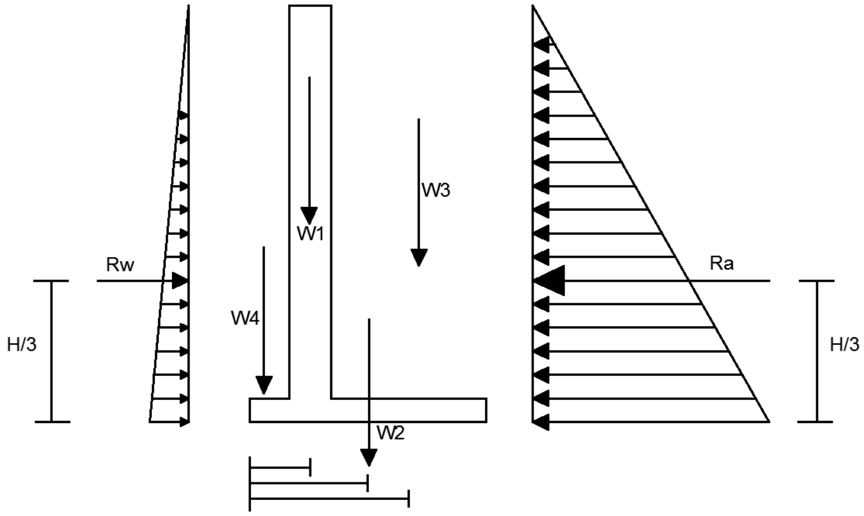
$M_0 = R_a \frac{H}{3} = 68.5115 \; x \frac{5.3}{3} = 121.037$

$\frac{M_{Resist\;overturn}}{M_0} = \frac{442.003}{121.037} = 3.652 \; > 2 \; (save)$

$F_{sliding} = \frac{\mu \sum \omega}{R_a} = \frac{0.55 \; x \; 242.1}{68.51151} = 1.94 > 1.5 \; (save)$

Unit weight of water = 998 kg/m^3 = 0.998kN/m^3

Considering that the reservoir will be full at some point and there will be water pressure on the retaining wall, the following calculations were made:



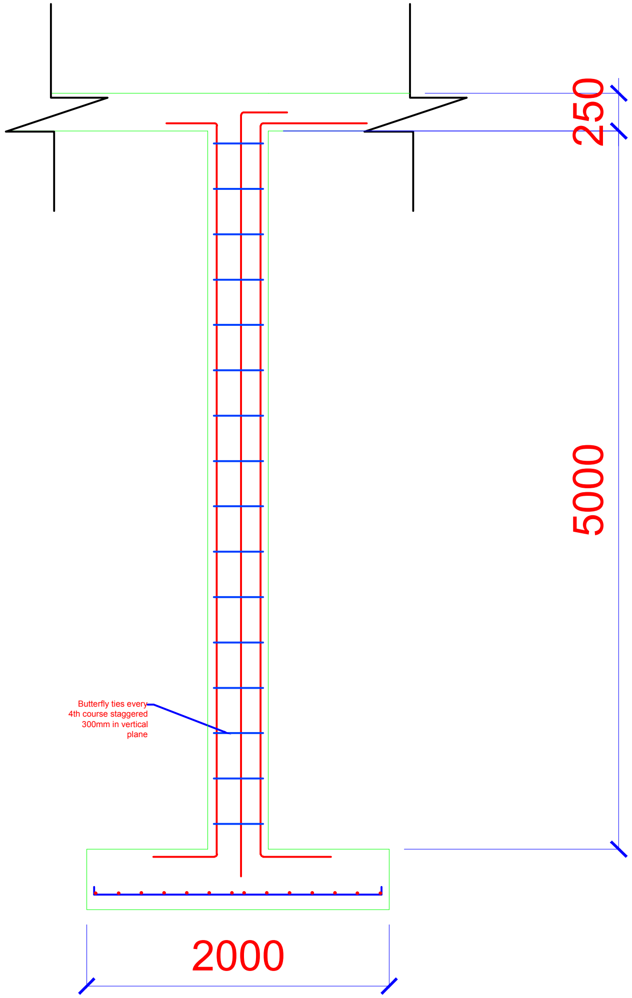
$\omega_4 = 0.5\ x\ 5\ x\ 0.998 = 2.495$
$\sum \omega = 268.895$
$M_4 = 2.495\ x\ 0.25 = 0.62375$
$\sum M = 442.62675$
$R_b = \frac{\gamma K_a H^2}{2} = \frac{0.998\ x\ 0.271\ x\ 5.3\ x\ 5.3}{2} = 3.7986$
$M_0 = (R_a - R_b)\frac{H}{3} = 64.713\ x \frac{5.3}{3} = 114.326$
$\frac{M_{Resist\ overturn}}{M_0} = \frac{442.62675}{114.326} = 3.872\ > 2\ (save)$
$F_{sliding} = \frac{\mu \sum \omega}{R_a} = \frac{1\ x\ 268.895}{64.713} = 4.155 > 1.5\ (save)$ (no friction between the wall and water)

The new values indicate with the reservoir full the changes of the retaining wall failure are significantly less than an empty reservoir. This indicate that the wall dimension can even be made smaller than it is currently. This is only a preliminary design, when the soil conditions are known a better design can be proposed.

Appendix D2 – Structural Design layouts

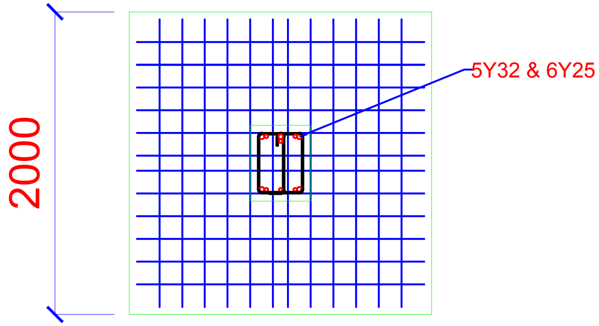
D2 – 1 Reservoir Column and Beam Design

D2 – 2 Retaining Wall Design Footing Detail



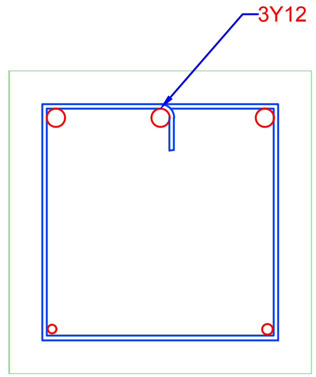
Reservoir Column Detail

Scale 1:50



Reservoir Column Detail

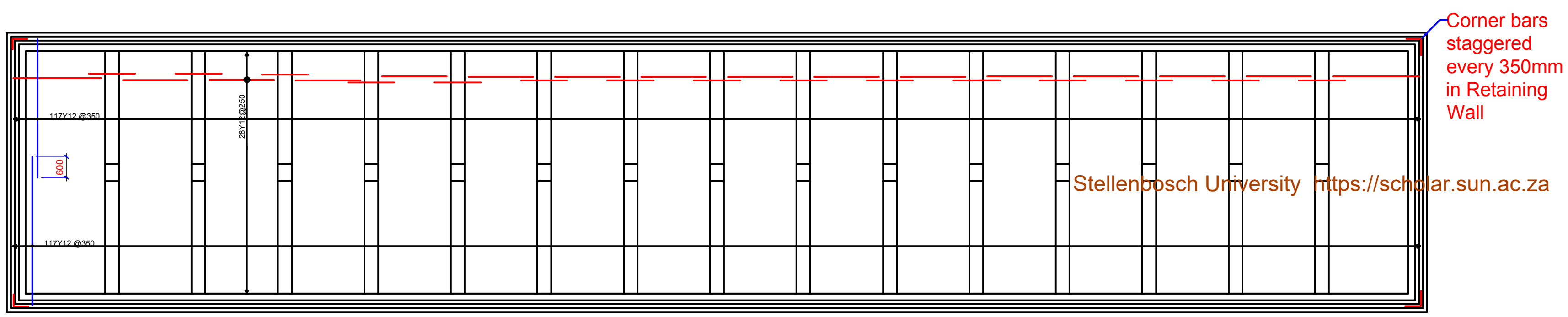
Scale 1:50



Beam Layout

Scale 1:10

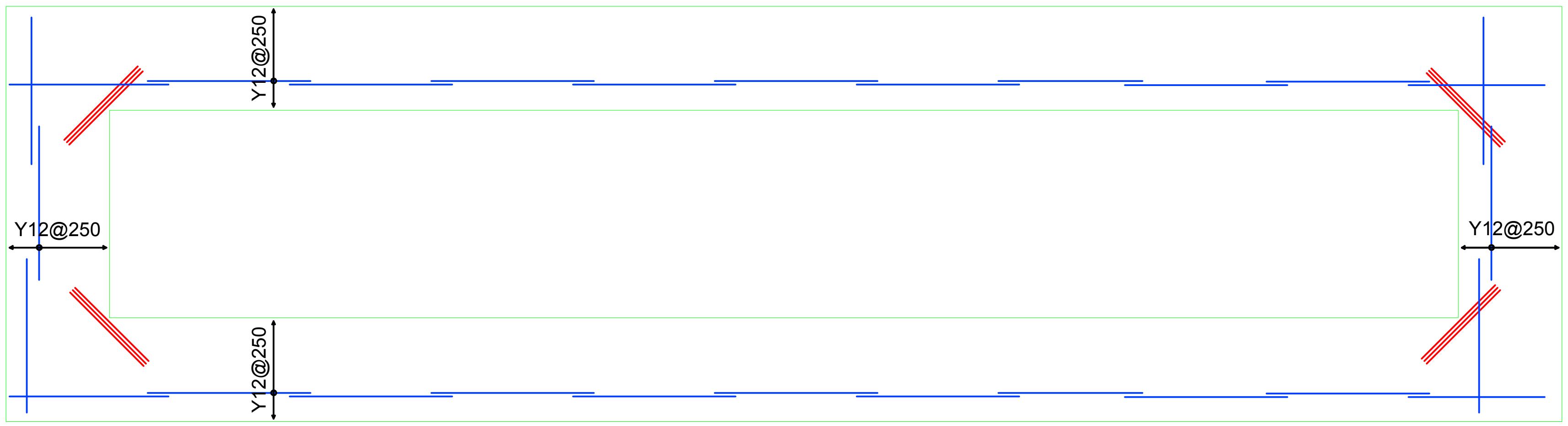
	CONTACT: Tel: 0826036825 P.O. Box 322, Durbanville 7551 Email: ingrid.rauch23@gmail.com	DESCRIPTION: Reservoir Beam and Column Design	DATE: 07-2018	SCALE: As Shown
			DRAWING NUMBER: AA-BBBB-CCC	

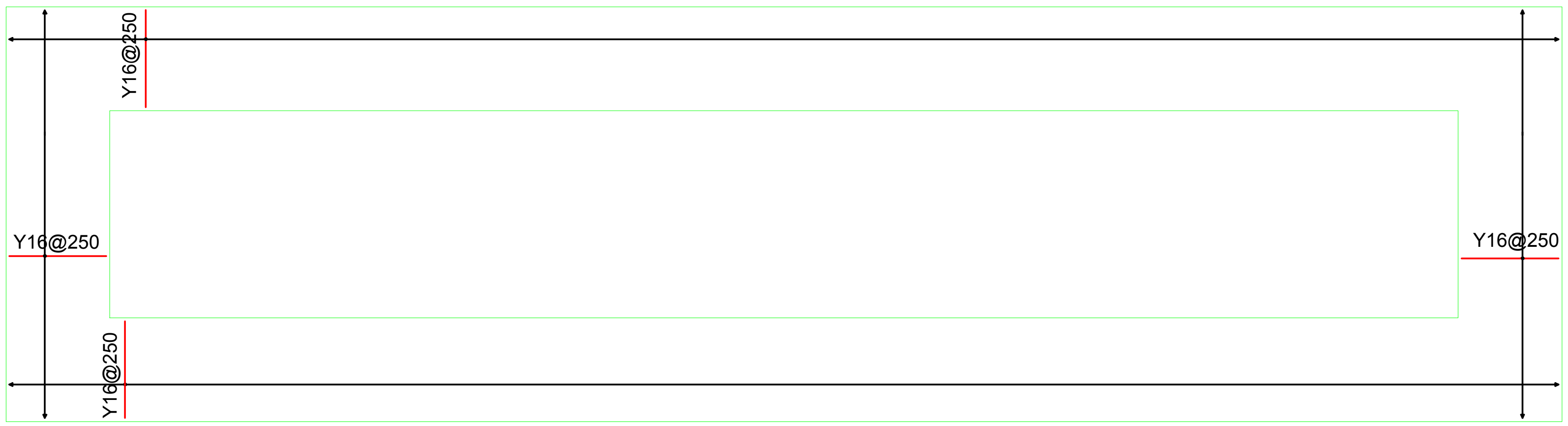


Stellenbosch University https://scholar.sun.ac.za

Slab Detail

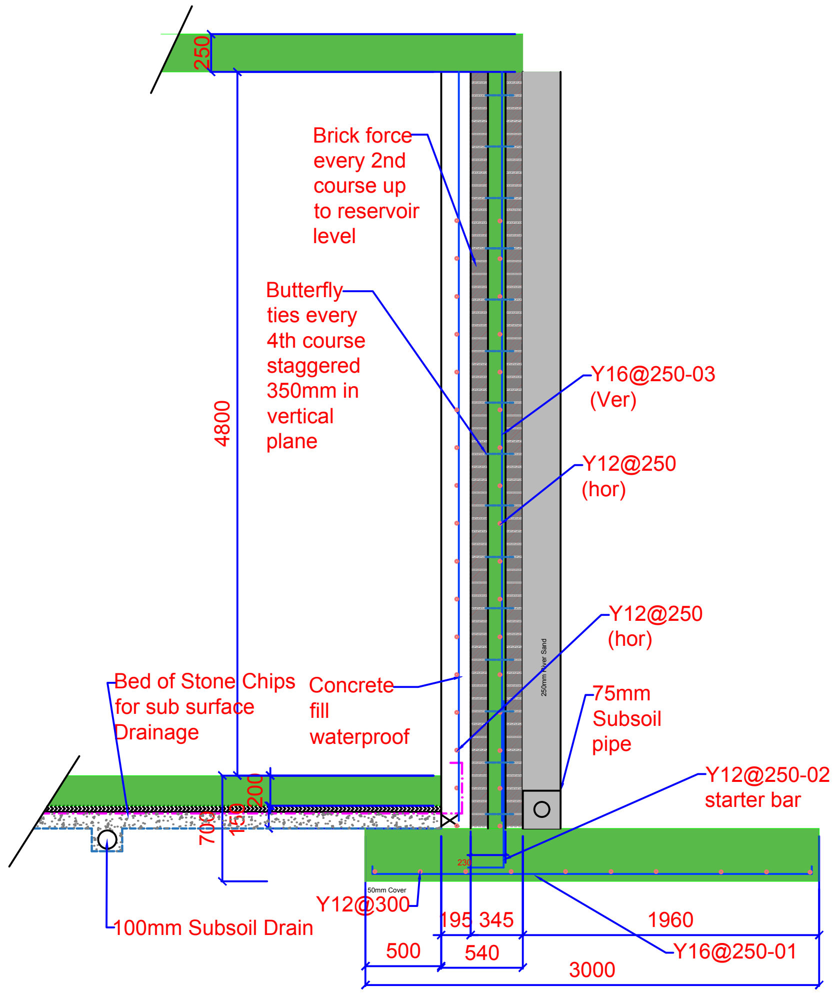
1:200





Retaining Wall Footing Detail

1:200



Reservoir Retaining Wall Detail

Scale 1:50

CONTACT:
Cell: 0826036825
E-mail: ingrid.rauch23@gmail.com
P.O. Box 322, Durbanville, 7551

CLIENT:
Stellenbosch Unversity

PROJECT:
Preliminary Design for stormwater harvesting Reservoir

DESCRIPTION:
Drawing Title Example

DATE:
07-2018

SCALE:
As Shown

DRAWING NUMBER:
AA-BBBB-CCC

D3 – Hydraulic calculations and Bio-retention design

Year	Month	Precipitation (mm)	Precipitation (m)	Parking area m^2	Water Lab Area m^2	Concrete Lab area m^2	Total Area	Monthly inflow = Volume (m^3) = Precipitation x area x slope	Reservoir capacity m3	$I_t + I_{\Delta t}$ m^3	Demand m^3	End Volume m^3	End capacity m^3	100% Demand m^3	100% End Volume m^3	100% End capacity m^3
2004	Aug	37	0.04	12008	4023.50	2568.06	18599.56	688.18	1400	688	512	176	176	614	74	74
	Sep	50.5	0.05	12008	4023.50	2568.06	18599.56	939.28	1400	1115	448	667	667	538	578	578
	Oct	140.6	0.14	12008	4023.50	2568.06	18599.56	2615.10	1400	3283	512	2771	1400	614	2668	1400
	Nov	9	0.01	12008	4023.50	2568.06	18599.56	167.40	1400	1567	384	1183	1183	461	1107	1107
	Dec	5.1	0.01	12008	4023.50	2568.06	18599.56	94.86	1400	1278	128	1150	1150	154	1125	1125
2005	Jan	61.5	0.06	12008	4023.50	2568.06	18599.56	1143.87	1400	2294	128	2166	1400	154	2141	1400
	Feb	0.2	0.00	12008	4023.50	2568.06	18599.56	3.72	1400	1404	512	892	892	614	789	789
	Mar	19.7	0.02	12008	4023.50	2568.06	18599.56	366.41	1400	1258	512	746	746	614	644	644
	Apr	83.4	0.08	12008	4023.50	2568.06	18599.56	1551.20	1400	2297	384	1913	1400	461	1837	1400
	May	128.8	0.13	12008	4023.50	2568.06	18599.56	2395.62	1400	3796	512	3284	1400	614	3181	1400
	Jun	155.1	0.16	12008	4023.50	2568.06	18599.56	2884.79	1400	4285	512	3773	1400	614	3670	1400
	Jul	84.4	0.08	12008	4023.50	2568.06	18599.56	1569.80	1400	2970	384	2586	1400	461	2509	1400
	Aug	117.3	0.12	12008	4023.50	2568.06	18599.56	2181.73	1400	3582	512	3070	1400	614	2967	1400
	Sep	48.2	0.05	12008	4023.50	2568.06	18599.56	896.50	1400	2296	448	1848	1400	538	1759	1400
	Oct	32.8	0.03	12008	4023.50	2568.06	18599.56	610.07	1400	2010	512	1498	1400	614	1396	1396

	Nov	29.7	0.03	12008	4023.50	2568.06	18599.56	552.41	1400	1952	384	1568	1400	461	1492	1400
	Dec	0	0.00	12008	4023.50	2568.06	18599.56	0.00	1400	1400	128	1272	1272	154	1246	1246
2006	Jan	0	0.00	12008	4023.50	2568.06	18599.56	0.00	1400	1272	128	1144	1144	154	1118	1118
	Feb	21.9	0.02	12008	4023.50	2568.06	18599.56	407.33	1400	1551	512	1039	1039	614	937	937
	Mar	7.8	0.01	12008	4023.50	2568.06	18599.56	145.08	1400	1184	512	672	672	614	570	570
	Apr	49.8	0.05	12008	4023.50	2568.06	18599.56	926.26	1400	1599	384	1215	1215	461	1138	1138
	May	155.5	0.16	12008	4023.50	2568.06	18599.56	2892.23	1400	4107	512	3595	1400	614	3492	1400
	Jun	87.8	0.09	12008	4023.50	2568.06	18599.56	1633.04	1400	3033	512	2521	1400	614	2419	1400
	Jul	125.6	0.13	12008	4023.50	2568.06	18599.56	2336.10	1400	3736	384	3352	1400	461	3275	1400
	Aug	101.9	0.10	12008	4023.50	2568.06	18599.56	1895.30	1400	3295	512	2783	1400	614	2681	1400
	Sep	34.6	0.03	12008	4023.50	2568.06	18599.56	643.54	1400	2044	448	1596	1400	538	1506	1400
	Oct	39.2	0.04	12008	4023.50	2568.06	18599.56	729.10	1400	2129	512	1617	1400	614	1515	1400
	Nov	47.3	0.05	12008	4023.50	2568.06	18599.56	879.76	1400	2280	384	1896	1400	461	1819	1400
	Dec	20	0.02	12008	4023.50	2568.06	18599.56	371.99	1400	1772	128	1644	1400	154	1618	1400
2007	Jan	3.6	0.00	12008	4023.50	2568.06	18599.56	66.96	1400	1467	128	1339	1339	154	1313	1313
	Feb	33.2	0.03	12008	4023.50	2568.06	18599.56	617.51	1400	1956	512	1444	1400	614	1342	1342
	Mar	39.7	0.04	12008	4023.50	2568.06	18599.56	738.40	1400	2138	512	1626	1400	614	1524	1400
	Apr	93.5	0.09	12008	4023.50	2568.06	18599.56	1739.06	1400	3139	384	2755	1400	461	2678	1400
	May	79.7	0.08	12008	4023.50	2568.06	18599.56	1482.38	1400	2882	512	2370	1400	614	2268	1400
	Jun	127.6	0.13	12008	4023.50	2568.06	18599.56	2373.30	1400	3773	512	3261	1400	614	3159	1400
	Jul	156.1	0.16	12008	4023.50	2568.06	18599.56	2903.39	1400	4303	384	3919	1400	461	3843	1400

	Aug	140.4	0.14	12008	4023.50	2568.06	18599.56	2611.38	1400	4011	512	3499	1400	614	3397	1400
	Sep	31.3	0.03	12008	4023.50	2568.06	18599.56	582.17	1400	1982	448	1534	1400	538	1445	1400
	Oct	68.1	0.07	12008	4023.50	2568.06	18599.56	1266.63	1400	2667	512	2155	1400	614	2052	1400
	Nov	41.7	0.04	12008	4023.50	2568.06	18599.56	775.60	1400	2176	384	1792	1400	461	1715	1400
	Dec	19.9	0.02	12008	4023.50	2568.06	18599.56	370.13	1400	1770	128	1642	1400	154	1617	1400
2008	Jan	19.6	0.02	12008	4023.50	2568.06	18599.56	364.55	1400	1765	128	1637	1400	154	1611	1400
	Feb	37.4	0.04	12008	4023.50	2568.06	18599.56	695.62	1400	2096	512	1584	1400	614	1481	1400
	Mar	24.3	0.02	12008	4023.50	2568.06	18599.56	451.97	1400	1852	512	1340	1340	614	1238	1238
	Apr	20.8	0.02	12008	4023.50	2568.06	18599.56	386.87	1400	1727	384	1343	1343	461	1266	1266
	May	80.7	0.08	12008	4023.50	2568.06	18599.56	1500.98	1400	2844	512	2332	1400	614	2229	1400
	Jun	101.3	0.10	12008	4023.50	2568.06	18599.56	1884.14	1400	3284	512	2772	1400	614	2670	1400
	Jul	240.4	0.24	12008	4023.50	2568.06	18599.56	4471.33	1400	5871	384	5487	1400	461	5411	1400
	Aug	117.6	0.12	12008	4023.50	2568.06	18599.56	2187.31	1400	3587	512	3075	1400	614	2973	1400
	Sep	129	0.13	12008	4023.50	2568.06	18599.56	2399.34	1400	3799	448	3351	1400	538	3262	1400
	Oct	15.9	0.02	12008	4023.50	2568.06	18599.56	295.73	1400	1696	512	1184	1184	614	1081	1081
	Nov	51.4	0.05	12008	4023.50	2568.06	18599.56	956.02	1400	2140	384	1756	1400	461	1679	1400
	Dec	8.4	0.01	12008	4023.50	2568.06	18599.56	156.24	1400	1556	128	1428	1400	154	1403	1400
2009	Jan	7.9	0.01	12008	4023.50	2568.06	18599.56	146.94	1400	1547	128	1419	1400	154	1393	1393
	Feb	10.7	0.01	12008	4023.50	2568.06	18599.56	199.02	1400	1599	512	1087	1087	614	985	985
	Mar	5.4	0.01	12008	4023.50	2568.06	18599.56	100.44	1400	1187	512	675	675	614	573	573
	Apr	43	0.04	12008	4023.50	2568.06	18599.56	799.78	1400	1475	384	1091	1091	461	1014	1014

	May	98.9	0.10	12008	4023.50	2568.06	18599.56	1839.50	1400	2931	512	2419	1400	614	2316	1400
	Jun	185.7	0.19	12008	4023.50	2568.06	18599.56	3453.94	1400	4854	512	4342	1400	614	4240	1400
	Jul	106.4	0.11	12008	4023.50	2568.06	18599.56	1978.99	1400	3379	384	2995	1400	461	2918	1400
	Aug	138	0.14	12008	4023.50	2568.06	18599.56	2566.74	1400	3967	512	3455	1400	614	3352	1400
	Sep	80.5	0.08	12008	4023.50	2568.06	18599.56	1497.26	1400	2897	448	2449	1400	538	2360	1400
	Oct	50.4	0.05	12008	4023.50	2568.06	18599.56	937.42	1400	2337	512	1825	1400	614	1723	1400
	Nov	84.7	0.08	12008	4023.50	2568.06	18599.56	1575.38	1400	2975	384	2591	1400	461	2515	1400
	Dec	0.3	0.00	12008	4023.50	2568.06	18599.56	5.58	1400	1406	128	1278	1278	154	1252	1252
2010	Jan	0.6	0.00	12008	4023.50	2568.06	18599.56	11.16	1400	1289	128	1161	1161	154	1135	1135
	Feb	21.1	0.02	12008	4023.50	2568.06	18599.56	392.45	1400	1553	512	1041	1041	614	939	939
	Mar	5.8	0.01	12008	4023.50	2568.06	18599.56	107.88	1400	1149	512	637	637	614	535	535
	Apr	13.1	0.01	12008	4023.50	2568.06	18599.56	243.65	1400	881	384	497	497	461	420	420
	May	142.9	0.14	12008	4023.50	2568.06	18599.56	2657.88	1400	3155	512	2643	1400	614	2540	1400
	Jun	132.3	0.13	12008	4023.50	2568.06	18599.56	2460.72	1400	3861	512	3349	1400	614	3246	1400
	Jul	62	0.06	12008	4023.50	2568.06	18599.56	1153.17	1400	2553	384	2169	1400	461	2092	1400
	Aug	63	0.06	12008	4023.50	2568.06	18599.56	1171.77	1400	2572	512	2060	1400	614	1957	1400
	Sep	32	0.03	12008	4023.50	2568.06	18599.56	595.19	1400	1995	448	1547	1400	538	1458	1400
	Oct	64.2	0.06	12008	4023.50	2568.06	18599.56	1194.09	1400	2594	512	2082	1400	614	1980	1400
	Nov	36.7	0.04	12008	4023.50	2568.06	18599.56	682.60	1400	2083	384	1699	1400	461	1622	1400
	Dec	11.2	0.01	12008	4023.50	2568.06	18599.56	208.32	1400	1608	128	1480	1400	154	1455	1400
2011	Jan	6.3	0.01	12008	4023.50	2568.06	18599.56	117.18	1400	1517	128	1389	1389	154	1364	1364

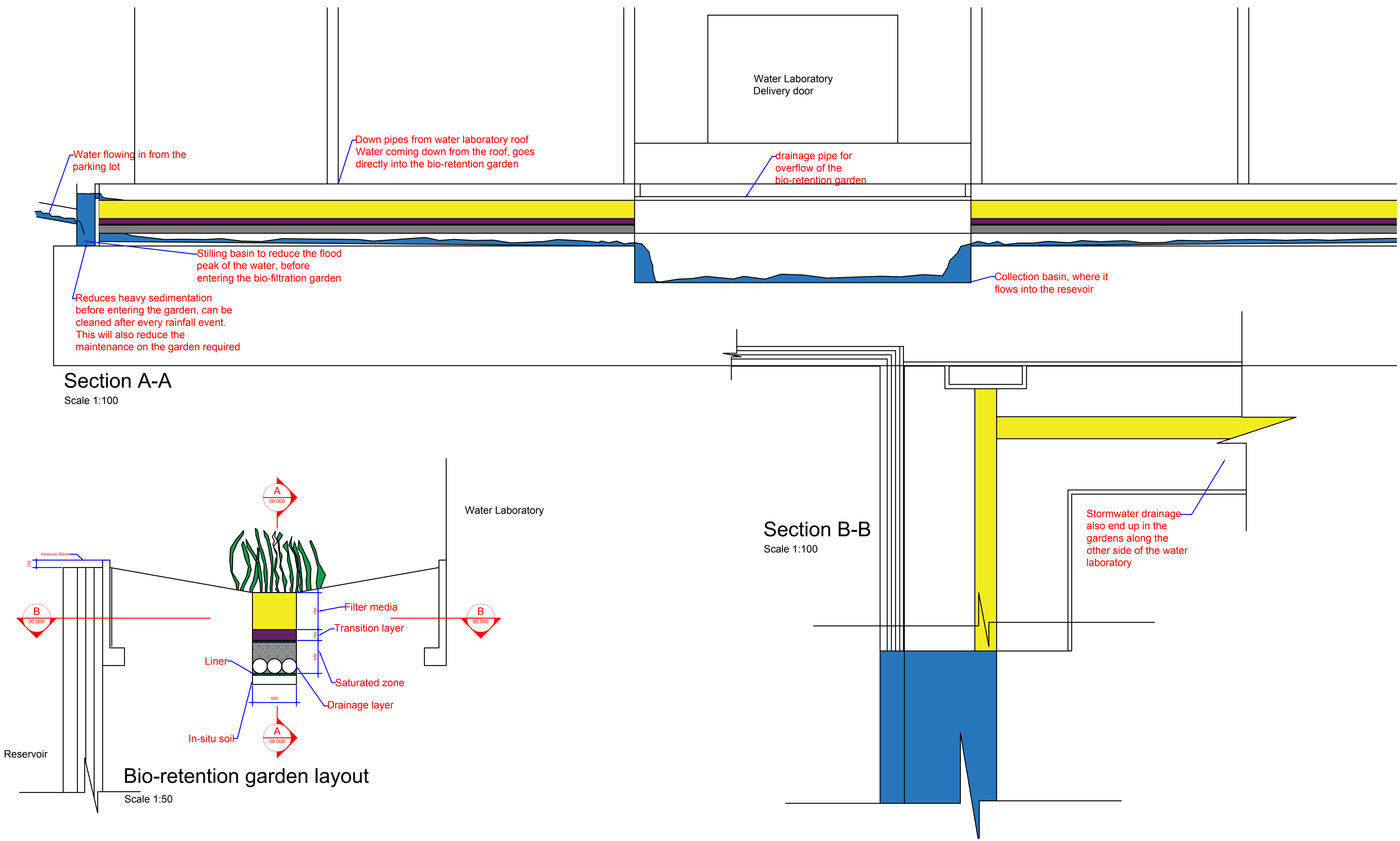
	Feb	3	0.00	12008	4023.50	2568.06	18599.56	55.80	1400	1445	512	933	933	614	831	831
	Mar	6.9	0.01	12008	4023.50	2568.06	18599.56	128.34	1400	1061	512	549	549	614	447	447
	Apr	50.6	0.05	12008	4023.50	2568.06	18599.56	941.14	1400	1490	384	1106	1106	461	1030	1030
	May	74.7	0.07	12008	4023.50	2568.06	18599.56	1389.39	1400	2496	512	1984	1400	614	1881	1400
	Jun	113.4	0.11	12008	4023.50	2568.06	18599.56	2109.19	1400	3509	512	2997	1400	614	2895	1400
	Jul	43.6	0.04	12008	4023.50	2568.06	18599.56	810.94	1400	2211	384	1827	1400	461	1750	1400
	Aug	94	0.09	12008	4023.50	2568.06	18599.56	1748.36	1400	3148	512	2636	1400	614	2534	1400
	Sep	41.5	0.04	12008	4023.50	2568.06	18599.56	771.88	1400	2172	448	1724	1400	538	1634	1400
	Oct	27.6	0.03	12008	4023.50	2568.06	18599.56	513.35	1400	1913	512	1401	1400	614	1299	1299
	Nov	44.4	0.04	12008	4023.50	2568.06	18599.56	825.82	1400	2226	384	1842	1400	461	1765	1400
	Dec	24.8	0.02	12008	4023.50	2568.06	18599.56	461.27	1400	1861	128	1733	1400	154	1708	1400
2012	Jan	1.1	0.00	12008	4023.50	2568.06	18599.56	20.46	1400	1420	128	1292	1292	154	1267	1267
	Feb	5.2	0.01	12008	4023.50	2568.06	18599.56	96.72	1400	1389	512	877	877	614	775	775
	Mar	32.1	0.03	12008	4023.50	2568.06	18599.56	597.05	1400	1474	512	962	962	614	860	860
	Apr	44.6	0.04	12008	4023.50	2568.06	18599.56	829.54	1400	1792	384	1408	1400	461	1331	1331
	May	87	0.09	12008	4023.50	2568.06	18599.56	1618.16	1400	3018	512	2506	1400	614	2404	1400
	Jun	140.7	0.14	12008	4023.50	2568.06	18599.56	2616.96	1400	4017	512	3505	1400	614	3403	1400
	Jul	148.2	0.15	12008	4023.50	2568.06	18599.56	2756.45	1400	4156	384	3772	1400	461	3696	1400
	Aug	169.6	0.17	12008	4023.50	2568.06	18599.56	3154.49	1400	4554	512	4042	1400	614	3940	1400
	Sep	121.8	0.12	12008	4023.50	2568.06	18599.56	2265.43	1400	3665	448	3217	1400	538	3128	1400
	Oct	98.7	0.10	12008	4023.50	2568.06	18599.56	1835.78	1400	3236	512	2724	1400	614	2621	1400

	Nov	8.6	0.01	12008	4023.50	2568.06	18599.56	159.96	1400	1560	384	1176	1176	461	1099	1099
	Dec	0	0.00	12008	4023.50	2568.06	18599.56	0.00	1400	1176	128	1048	1048	154	1022	1022
2013	Jan	15.7	0.02	12008	4023.50	2568.06	18599.56	292.01	1400	1340	128	1212	1212	154	1186	1186
	Feb	66.5	0.07	12008	4023.50	2568.06	18599.56	1236.87	1400	2449	512	1937	1400	614	1834	1400
	Mar	17.1	0.02	12008	4023.50	2568.06	18599.56	318.05	1400	1718	512	1206	1206	614	1104	1104
	Apr	57.9	0.06	12008	4023.50	2568.06	18599.56	1076.91	1400	2283	384	1899	1400	461	1822	1400
	May	72.7	0.07	12008	4023.50	2568.06	18599.56	1352.19	1400	2752	512	2240	1400	614	2138	1400
	Jun	156	0.16	12008	4023.50	2568.06	18599.56	2901.53	1400	4302	512	3790	1400	614	3687	1400
	Jul	96.4	0.10	12008	4023.50	2568.06	18599.56	1793.00	1400	3193	384	2809	1400	461	2732	1400
	Aug	229	0.23	12008	4023.50	2568.06	18599.56	4259.30	1400	5659	512	5147	1400	614	5045	1400
	Sep	103.7	0.10	12008	4023.50	2568.06	18599.56	1928.77	1400	3329	448	2881	1400	538	2791	1400
	Oct	41.1	0.04	12008	4023.50	2568.06	18599.56	764.44	1400	2164	512	1652	1400	614	1550	1400
	Nov	135.1	0.14	12008	4023.50	2568.06	18599.56	2512.80	1400	3913	384	3529	1400	461	3452	1400
	Dec	2.7	0.00	12008	4023.50	2568.06	18599.56	50.22	1400	1450	128	1322	1322	154	1297	1297
2014	Jan	45.8	0.05	12008	4023.50	2568.06	18599.56	851.86	1400	2174	128	2046	1400	154	2020	1400
	Feb	2	0.00	12008	4023.50	2568.06	18599.56	37.20	1400	1437	512	925	925	614	823	823
	Mar	47.9	0.05	12008	4023.50	2568.06	18599.56	890.92	1400	1816	512	1304	1304	614	1202	1202
	Apr	28.6	0.03	12008	4023.50	2568.06	18599.56	531.95	1400	1836	384	1452	1400	461	1375	1375
	May	71.8	0.07	12008	4023.50	2568.06	18599.56	1335.45	1400	2735	512	2223	1400	614	2121	1400
	Jun	209.8	0.21	12008	4023.50	2568.06	18599.56	3902.19	1400	5302	512	4790	1400	614	4688	1400
	Jul	126.9	0.13	12008	4023.50	2568.06	18599.56	2360.28	1400	3760	384	3376	1400	461	3299	1400

	Aug	117.9	0.12	12008	4023.50	2568.06	18599.56	2192.89	1400	3593	512	3081	1400	614	2978	1400
	Sep	30.9	0.03	12008	4023.50	2568.06	18599.56	574.73	1400	1975	448	1527	1400	538	1437	1400
	Oct	4.7	0.00	12008	4023.50	2568.06	18599.56	87.42	1400	1487	512	975	975	614	873	873
	Nov	42.8	0.04	12008	4023.50	2568.06	18599.56	796.06	1400	1771	384	1387	1387	461	1311	1311
	Dec	6.3	0.01	12008	4023.50	2568.06	18599.56	117.18	1400	1505	128	1377	1377	154	1351	1351
2015	Jan	18	0.02	12008	4023.50	2568.06	18599.56	334.79	1400	1711	128	1583	1400	154	1558	1400
	Feb	6	0.01	12008	4023.50	2568.06	18599.56	111.60	1400	1512	512	1000	1000	614	897	897
	Mar	2.2	0.00	12008	4023.50	2568.06	18599.56	40.92	1400	1041	512	529	529	614	426	426
	Apr	8.8	0.01	12008	4023.50	2568.06	18599.56	163.68	1400	692	384	308	308	461	231	231
	May	32.4	0.03	12008	4023.50	2568.06	18599.56	602.63	1400	911	512	399	399	614	296	296
	Jun	124.4	0.12	12008	4023.50	2568.06	18599.56	2313.79	1400	2713	512	2201	1400	614	2098	1400
	Jul	105.3	0.11	12008	4023.50	2568.06	18599.56	1958.53	1400	3359	384	2975	1400	461	2898	1400
	Aug	43.1	0.04	12008	4023.50	2568.06	18599.56	801.64	1400	2202	512	1690	1400	614	1587	1400
	Sep	22	0.02	12008	4023.50	2568.06	18599.56	409.19	1400	1809	448	1361	1361	538	1272	1272
	Oct	6.4	0.01	12008	4023.50	2568.06	18599.56	119.04	1400	1480	512	968	968	614	866	866
	Nov	0	0.00	12008	4023.50	2568.06	18599.56	0.00	1400	968	384	584	584	461	507	507
	Dec	16.5	0.02	12008	4023.50	2568.06	18599.56	306.89	1400	891	128	763	763	154	738	738
2016	Jan	0	0.00	12008	4023.50	2568.06	18599.56	0.00	1400	763	129	634	634	155	608	608
	Feb	0	0.00	12008	4023.50	2568.06	18599.56	0.00	1400	634	130	504	504	156	478	478
	Mar	56.7	0.06	12008	4023.50	2568.06	18599.56	1054.60	1400	1559	131	1428	1400	157	1402	1400
	Apr	53.9	0.05	12008	4023.50	2568.06	18599.56	1002.52	1400	2403	132	2271	1400	158	2244	1400

	May	18.1	0.02	12008	4023.50	2568.06	18599.56	336.65	1400	1737	133	1604	1400	160	1577	1400
	Jun	104.3	0.10	12008	4023.50	2568.06	18599.56	1939.93	1400	3340	134	3206	1400	161	3179	1400
	Jul	104.7	0.10	12008	4023.50	2568.06	18599.56	1947.37	1400	3347	135	3212	1400	162	3185	1400
	Aug	84.9	0.08	12008	4023.50	2568.06	18599.56	1579.10	1400	2979	136	2843	1400	163	2816	1400
	Sep	56	0.06	12008	4023.50	2568.06	18599.56	1041.58	1400	2442	137	2305	1400	164	2277	1400
	Oct	21.9	0.02	12008	4023.50	2568.06	18599.56	407.33	1400	1807	138	1669	1400	166	1642	1400
	Nov	1.4	0.00	12008	4023.50	2568.06	18599.56	26.04	1400	1426	139	1287	1287	167	1259	1259
	Dec	8.9	0.01	12008	4023.50	2568.06	18599.56	165.54	1400	1453	140	1313	1313	168	1285	1285
2017	Jan	13.5	0.01	12008	4023.50	2568.06	18599.56	251.09	1400	1564	141	1423	1400	169	1394	1394
	Feb	0	0.00	12008	4023.50	2568.06	18599.56	0.00	1400	1400	142	1258	1258	170	1230	1230
	Mar	7.7	0.01	12008	4023.50	2568.06	18599.56	143.22	1400	1401	143	1258	1258	172	1230	1230
	Apr	33.8	0.03	12008	4023.50	2568.06	18599.56	628.67	1400	1887	144	1743	1400	173	1714	1400
	May	10.5	0.01	12008	4023.50	2568.06	18599.56	195.30	1400	1595	145	1450	1400	174	1421	1400
	Jun	142.9	0.14	12008	4023.50	2568.06	18599.56	2657.88	1400	4058	146	3912	1400	175	3883	1400
	Jul	61.7	0.06	12008	4023.50	2568.06	18599.56	1147.59	1400	2548	147	2401	1400	176	2371	1400
	Aug	69.2	0.07	12008	4023.50	2568.06	18599.56	1287.09	1400	2687	148	2539	1400	178	2509	1400
	Sep	26.4	0.03	12008	4023.50	2568.06	18599.56	491.03	1400	1891	149	1742	1400	179	1712	1400
	Oct	36.4	0.04	12008	4023.50	2568.06	18599.56	677.02	1400	2077	150	1927	1400	180	1897	1400
	Nov	46.7	0.05	12008	4023.50	2568.06	18599.56	868.60	1400	2269	151	2118	1400	181	2087	1400
	Dec	20	0.02	12008	4023.50	2568.06	18599.56	371.99	1400	1772	152	1620	1400	182	1590	1400

D4 – Bio-retention garden layout design



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Cell: 0826036825 E-mail: ingrid.rauch23@gmail.com P.O. Box 322, Durbanville, 7551	Stellenbosch Unversity	Preliminary for Bio-retention garden	Drawing Title Example	07-2018	As Shown

DRAWING NUMBER:
AA-BBBB-CCC