Appendix B

Monitoring Plan

Submitted to:
CVC

OPTIONS FOR THE MONITORING OF RESIDENTIAL LANDS

- STROMWATER AND WATER USE -

January 15, 2014

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1. Introduction

The following document has been developed to aid municipalities, regional governments and agencies in selecting, developing and implementing monitoring programs on residential lands for both potable water use and stormwater management as part of Low Impact Development (LID) retrofits. LID retrofits are intended to use less potable water, keep rainwater within individual residential properties and manage what and how much goes into our storm sewer system. By doing so, LID can protect the individual home and the environment while also saving money. While LIDs are known to be highly effective, a municipality, regional government and or agency may wish to quantify LID performance within the residential context through a targeted monitoring program.

Monitoring of stormwater and water use is an important tool which can provide a means to evaluate the environmental risk as well as the benefits. Monitoring can provide valuable information on the effectiveness of LID in reducing stormwater peak flows, volumes, in-stream erosion, pollutant loadings and potable water use. This data can be then be used within the decision making process to establish SWM priorities, refine design guidance and establish policies both monetary (utilities, rebates, grants, and capital budgets) and development (in-fill/ redevelopments, by-laws and permits).

1.1 Purpose

The following is intended to aid in the determination of the effectiveness of LID retrofits within residential lands to achieve the following objectives:

- Reduce potable water used for outdoor irrigation
- Reduce stormwater volumes and peak flows
- Improve the water quality of stormwater flows entering the environment

This document is primarily designed to describe the fundamental monitoring approaches for residential lands and to assist practitioners selecting, planning and budgeting for residential monitoring programs. In preparing this document, it is assumed that the reader has a basic understanding of monitoring requirements and sampling procedures.

Once a preferred approach is selected, it is assumed that the practitioners will obtain the necessary expertise required to select appropriate sites, developed and standard operating procedure, analyze collected data and perform the necessary quality assurance and quality controls. Other resources can be used to supplement this document to provide additional background on LID monitoring, in order to refine goals and objectives, procedural guidance on how to conduct sampling, flow monitoring and or model based analysis, including but not limited to:

- Stormwater Management Monitoring Strategy Report (CVC, Draft October, 2012)
- Protocol for Analytical Methods used in the Assessment of Properties under Part XV.1 of the Environmental Protection Act (Laboratory Services Branch, MOE, March 9, 2004, amended July 1, 2011)
- Urban Stormwater BMP Performance Monitoring (October 2009)
- Water Quality (Tchobangolous, G., 1985)
- NPDES Storm Water Sampling Guidance Manual (Smokley, C.K., 1993)
- A guide to short term flow surveys of sewer systems (Water research Centre, 1987)
- Guidance on Sampling and Analytical Methods (OMEE , December 1996)

1.2 Context & Objectives

A residential LID stormwater monitoring program may be undertaken by a municipality, regional government and or agency in order to:

- to develop baseline data in order to assess the future need for LID retrofits within a target area or land use
- to provide performance data of LID BMPs at a smaller scale, in order to quantify the benefits from larger retrofit programs
- to validate performance and or environmental assumptions (modelled or calculated)
- to demonstrate and or validate the benefits of LIDs to remove or divert loading from existing infrastructure (infrastructure resilience and optimization) as key strategy for Climate Change Adaptation
- to refine municipal/regional engineering standards and design criteria for LID implementation

1.3 Document Structure

The followings section summarizes the report organization and architecture. The report has been organized into the following three (3) sections:

Section 1 is a general document introduction and summarizes the purpose and objectives

Section 2 provides an overview of residential stormwater monitoring (previous studies) and details the residential stormwater monitoring options at the catchment scale, site scale and using desktop analysis

Section 3 provides the options and details for residential water use monitoring options

2. Residential Stormwater Monitoring

2.1 Residential Stormwater Overview

A residential property typically has one or more of the following common elements including roof areas (house and out-buildings), driveways, walkways and patios, turf areas and gardens. In many cases the impermeable surfaces (roof areas, driveways, walkways and patios) can total 37% to more than 75% of the total land area for single family residential lot to row-housing/town homes respectively (NSQD, Version 1.1, City of London, City of Hamilton, City of Toronto).

The impervious surfaces prevent rainwater from being distributed evenly across the ground surface and absorbed into the ground. Instead the water is concentrated into channels and other drainage infrastructure where it can easily increase in both force and velocity. In addition as rainwater passes over these impervious surfaces, it picks up sediment and other particles, nutrients, pathogens and chemicals that cause pollution to our rivers and lakes.

In older developments, built before the development of current stormwater management, rainwater that enters a ditch, storm sewer system or that flows from a residence directly to a nearby stream or lake is sometimes left untreated. Although an individual house or lot is a relatively small area when considering a larger village, town or city, polluted stormwater runoff from all residential areas collectively poses a great threat to local waterways and the broader environment.

LIDs are a set of stormwater best management practices (BMPs) that can be implemented by individual landowners to protect the environment, reduce stormwater volumes, improve water quality and reduce the use of potable water used for irrigation of conventional turf areas. Through the support of LID BMPs on residential lands by municipalities, regional governments and agencies, homeowners can better manage stormwater runoff on the site, and help to infiltrate stormwater into the ground. This approach has the potential to provide broader watershed benefits.

2.2 Previous Studies

In developing this document, previously completed studies were compiled; review and relevant elements were incorporated into the various residential stormwater monitoring options. The following section provides a series of summary tables which detail previous Residential Stormwater Studies (**Table 1**) and previous Event Mean Concentration (EMC) Studies (**Table 2**).

Table 1 – Summary of Previous Residential Stormwater Monitoring Studies

Study Name	Type	Reference
Stormwater Monitoring of a Residential Catchment Area, Vancouver B.C.	Single Catchment (13ha) – single family and townhomes	L.G. Swain, B.C Ministry of the Env. (June 1983)
Performance Assessment of a Stormwater Retrofit Pond, Harding Park, Richmond Hill, ON	Single Catchment (16.8ha)	Stormwater Assessment Monitoring and Performance (SWAMP) Program, June 2002
Evaluation of Residential Lot Level Stormwater Management Practices	"paired watershed" study of 3 catchments	T. Van Seters, TRCA STEP (2013)
Impacts of Extension Education of Improving Residential Stormwater Quality: Monitoring Results	"paired watershed" study of 2 catchments	M.E. Dietz et al., Journal of Extension (2002) Vol 40, No.6

Table 2 – Summary of Previous EMC Monitoring Studies

Study Name	Date	Details	
Credit Valley Conservation, 2008 "Impact Monitoring Study"	2007-08	26 events, >5mm	CVC, 2008
City of Hamilton Stormwater Master Plan - Class Environmental Assessment Report (City-Wide)"	2007, EMC reported from 1989-03	typical in-stream water quality for different land uses,	Aquafor Beech, 2007
Lower Rideau Watershed Strategy"	2005, EMC reported from 1989-03	11 stations sampled between 1989 to 2003	Robinson Consultants Inc & Aquafor Beech Ltd, 2005
Results of the Nationwide Urban Runoff Program, Volume 1 - Final Report	1983	81 sites in 22 different cities, and includes more than 2,300 separate storm events	U.S. EPA,1983, PB84-185552
Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban Best Management Practices	1987, EMC reported from 1980-81	27 storm events were sampled at multiple sites within the specified land use.	Schueler, Thomas R. 1987
Technical Memorandum 1, Urban Stormwater Pollution Assessment, prepared for North Carolina Department of Environment and Natural Resources	1990's	Data summarized in Appendix PLOAD version 3.0. User's Manual, January 2001. U.S. Environmental Protection Agency.	CH2M HILL, 2000
Characterization of Nonpoint Sources and Loadings to Corpus Christi Bay National Estuary Program Study Area, Corpus Christi Bay National Estuary Program/USGS/NRCS, CCBNEP-05, January 1996, Table IV.9	1996, EMC reported from 1992-93	5 sampling stations, 6 events/station	Raird, Charles, Marshall Jennings, David Ockerman, and Tim Dybale, 1996
Stormwater Management Manual for Western Washington: Volume I Minimum Technical Requirements	2000, EMC reported from 1990-96	See Table 1.1. of [1]Strecker, Eric W., et al, Analysis of Oregon Urban Runoff Water Quality Monitoring Data Collected From 1990 to 1996, The Oregon Association of Clean Water Agencies, 1997	Washington State Department of Ecology, 2000 Publication No. 99-11, August, 2000
Water Quality and Quantity Inputs for the Urban Creeks – Future Needs Assessment.	20 years of data, most comprehensive U.S program to date	85 Commercial, 30 Industrial, 42 Manufacturing, 15 Office, 115 Single-Family Residential, 33 Transportation and 8 Undeveloped land uses monitored	Barrett, M.E., A.M. Quenzer and D.R. Maidment (1998). Center for Research in Water Resources, Bureau of Engineering Research, The University of Texas at Austin.
The Quality of Urban Stormwater in Britain and Europe: Database and Recommended Values For Strategic Planning Models	Completed 2001, 20+ years	160 separate urban stormwater quality studies as flow-proportional EMCs, involving 676 individual catchments, 476 from North America	University of Leeds (2001)

2.3 Residential LID Stormwater Monitoring Options

As a component of municipal, regional and agency programs to encourage LID BMPs within residential lands, a monitoring program designed to assess the efficacy and performance of the residential LIDs may be undertaken to understand the benefit of residential lots with LIDs vs. those without in order to achieve the aforementioned objectives. A residential LID monitoring program may be undertaken using:

1. Catchment Scale Monitoring program (see Section 2.4)
2. Site Scale Monitoring program or (see Section 2.5)
3. Desktop Analysis (see Section 2.6)

The following sections provides a general discussion in the context of residential monitoring program as it relates to staffing considerations, data collection approaches for water quality and quantity and monitoring equipment requirements.

2.3.1 Staffing Considerations

Staffing needs for each monitoring program type will vary with each project and can affect the program schedule, results and costs. Staffing needs must be determined prior to undertaking a residential monitoring program based on:

- number of monitoring locations,
- size of the area to be monitored
- distance between monitoring locations
- techniques and technology to be used
- number of parameters collected
- safety considerations (in-stream work, fall protection, confined space entry, etc.)

Training of monitoring personnel is extremely important to the success of any monitoring program, as monitoring performed by untrained personnel may result in missing data (i.e. seasonal or event), unrepresentative data and results, errors and potentially the need for repeated efforts.

2.3.2 Data Collection Approaches

The collection of stormwater quantity, quality or both quantity and quality can be included within the scope of the monitoring program depending on the desired outcomes. The scope is generally determined by financial considerations, equipment needs and staff resources.

2.3.2.1 Water Quantity

Water quantity or flow rate monitoring is defined as the quantity of flow discharged from a discrete outfall per unit time. Flow rates and volumes can either be measured specifically (absolute) or estimated based on rainfall measurements, velocities or depths of flows (non-absolute), see Section 2.3.3.2. Flow monitoring is less costly than water quality monitoring and requires fewer staff hours to complete. Specialized equipment is required if continuous data is required.

2.3.2.2 Water Quality

Water quality monitoring is generally more labor intensive as compared to water quantity monitoring and can require specialized equipment and can have considerable costs particularly in regards to the laboratory fees associated with analyzing the collected samples. There are three basic aspects of sampling:

- Type – grab sample vs. composite sampling
- Collection techniques - manual vs. automated
- Frequency – determined by desired outcomes and catchment characteristics.

Consideration should also be given to seasonal effects i.e. sampling within each of the seasons (spring, summer, fall, and winter).

2.3.2.3 Water Quantity and Water Quality

A widely used and preferred approach for water quantity and water quality monitoring is the use of the Event Mean Concentration (EMC) approach (see **Table 2**). EMCs were developed by the EPA's Nationwide Urban Runoff Program (NURP) (1983) to serve as a national measure of the magnitude of urban runoff, specifically pollutant loadings.

The event Mean Concentration (EMC) is the mean concentration of a selected constituent or pollutant over a unit time of flow, generally during a wet-weather (storm) event. The EMC is used to measure pollutant loadings from a defined catchment area. This approach permits the determination of pollutant mass loadings. Mass loadings are the true measure of the effectiveness of implemented stormwater management measures and have been utilized to gauge the performance of BMPs implemented within municipalities across the province of Ontario, Canada, the United States and Europe and is fundamental in the development of emerging databases such as the International Stormwater Best Management Practice Database (www.LIDdatabase.org). The collection of EMC data permits comparative analysis with other data collected in a similar manner.

Section 3.5.1 of the Blue Book/ Water Management: Goals, Policies, Objectives and Implementation Procedures of the Ministry of the Environment (1994, reprinted 1999) sets out procedures for effluent requirements. Of interest is the determination of effluent requirements are expressed as "waste loadings and/or concentrations". Meeting the PWQO "should be determined from data that adequately reflect the spatial and temporal variations of the quality of the waterbody under consideration". This must be accomplished through stormwater quality analyses of event mean concentration (EMC) values for various representative pollutants.

With regard to sampling techniques, there are three (3) major considerations:

1. How many samples (or sub-samples which form a composite) should be collected during each storm event to determine the EMC for a given storm event?
2. When multiple samples are collected, should they be based on flow (flow-weighted), time (time-weighted) or manual (grab samples)? Should these be individual (discrete samples) or combined (composite sample)?
3. How many storm events should be sampled to obtain a reliable EMC?

The number of samples collected during a given storm event is best determined by initiating a sampling event for every increment of flow (flow-proportional) for the entirety of the largest storm event. For a composite sample, this will also capture one or more samples from the smallest storm event. This is illustrated in **Figure 1**, where each sub-sample represents the same unit volume of flow. The circles represent individual flow-proportional sub-samples, whereas the triangles represent individual grab samples during baseflow conditions.

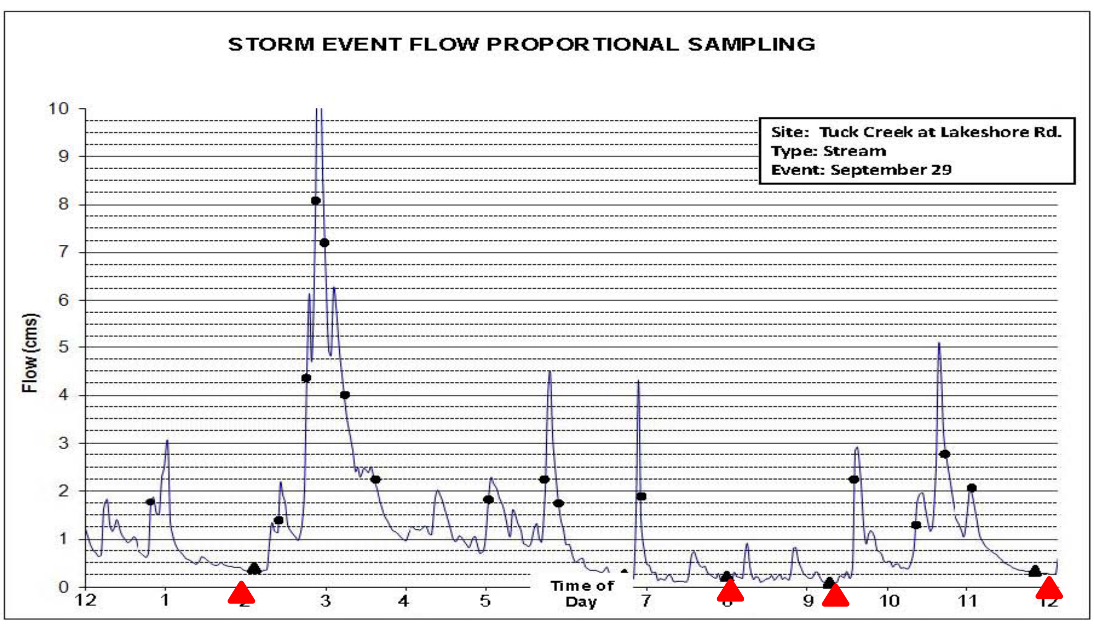

Figure 1: An example of flow-proportional sampling during a 12-hour period. (Aquafor Beech Limited, 2006).

The third consideration is the number of storm events that should be monitored. Since no two storms will be alike (in terms of intensity, duration and frequency), it has been suggested that 8 to 10 storm events should be sampled before an representative EMC or Average Event Mean Concentration (AEMC) can be determined (see **Figure 2**). Below this number, the variance in the results will render the results virtually meaningless.

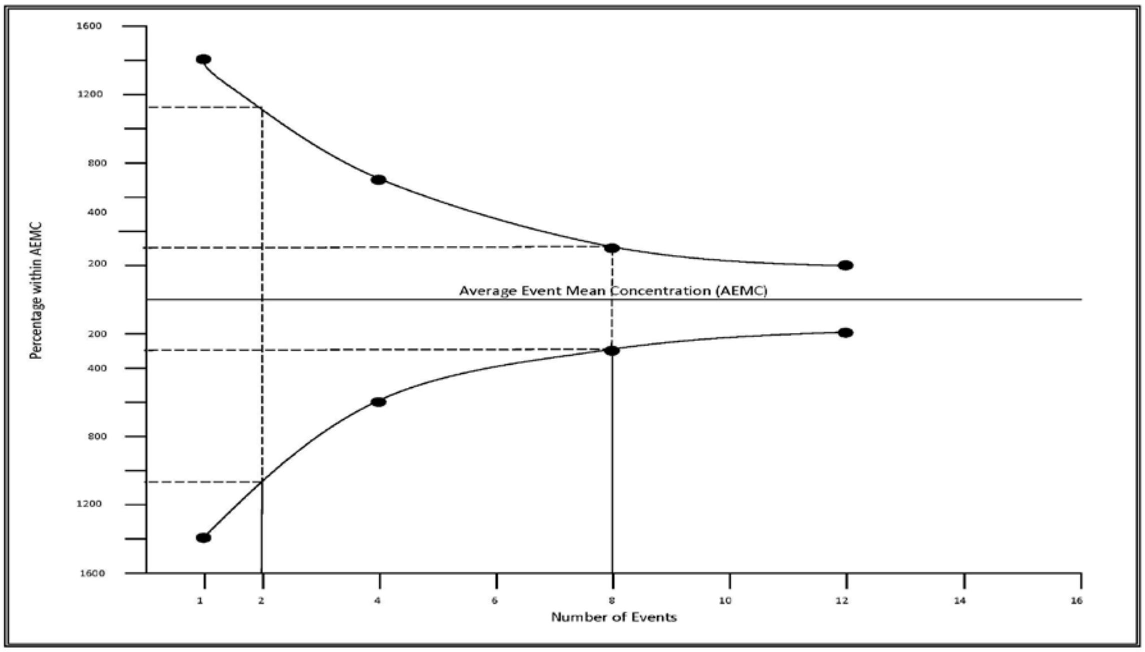

FIGURE 2

Figure 2: Illustrative Figure Showing Expected Variability of Individual Storms as a Function of the Number of Storms Monitored.

From a statistical perspective, when the sample population is <30 and the Student's t-test is applied to the population, the greater the population of storm events, the narrower the confidence interval. This is illustrated in the nomogram in **Figure 3**, where the acceptable variance (± X%) of the 95% confidence interval and an acceptable variance of the result (as a fraction of the mean) will give the number of storms that are required.

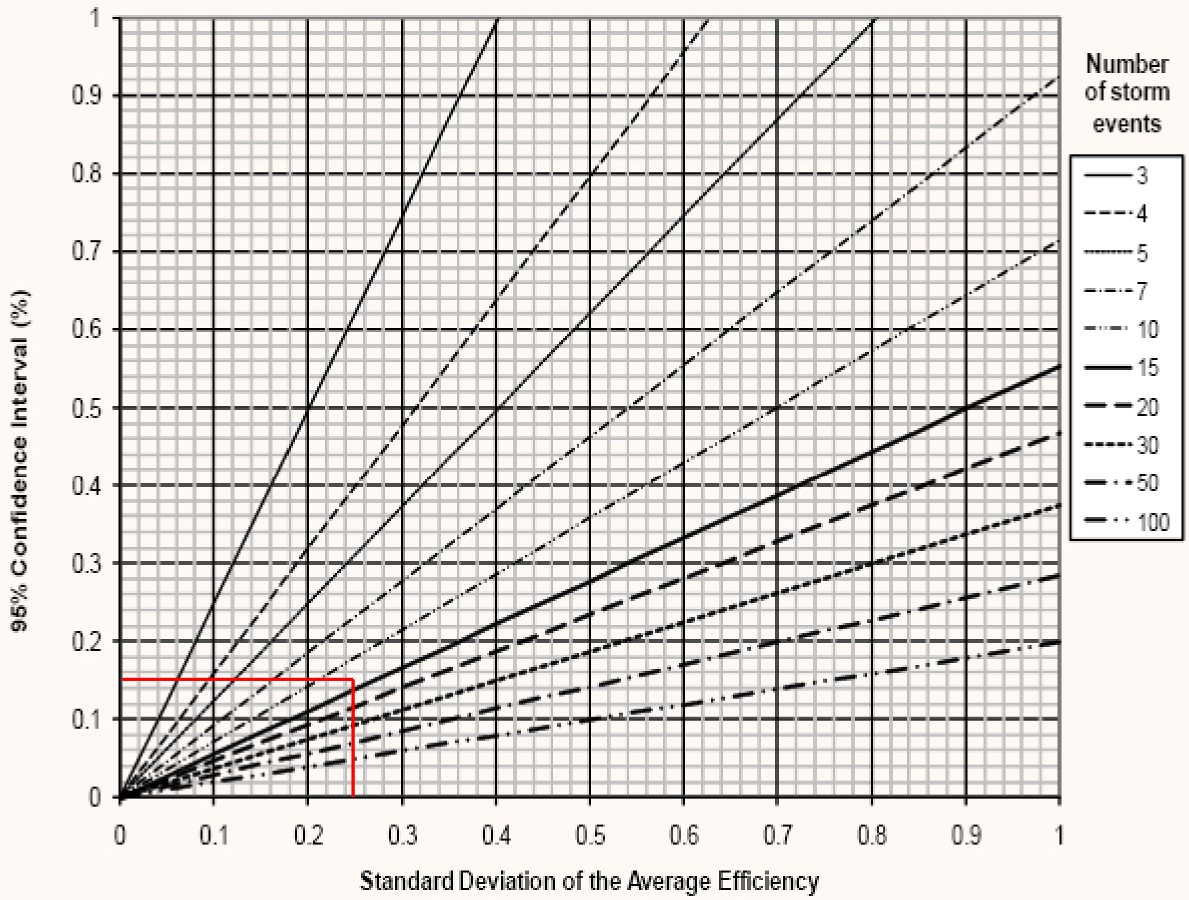

Figure 5.1: Relationship between number of storm events and standard deviation for a 95% confidence interval.

Figure 3: Relationship Between the Number of Storm Events and Standard deviation for a 95% Confidence Interval. In this case, a confidence interval of ±15% and standard deviation of 25% would require 13 storm events to be monitored. Erikson, A.J. et al., (2010)

Relationship between Nutrients and Total Suspended Solids: Previous studies show a strong relationship between nutrient concentrations and Total Suspended Solids. Collection of nutrient data and TSS data is therefore valuable. As such, as a method to limit analytical costs, TSS is often sampled as a surrogate parameter for other constituents/pollutants of concern.

Influence of Land Uses: Previous studies have shown that the concentrations from different land uses (i.e. industrial, commercial and residential) do not vary as much as is generally thought. Typically EMC's from different land uses are generally ± 20 percent.

Additional Considerations

Based on the assumptions that the LID residential retrofits will target roof water for treatment and or infiltration that the EMC results may demonstrate an increase in the post retrofit scenario as the relatively 'clean' roof water will no longer be providing dilution to road runoff during events. However the retrofit scenario may produce a corresponding decrease in load for the same event. The latter is a potentially the most environmentally-desirable result and should be evaluated as a measure of success of the retrofit approach.

2.3.3 Monitoring Equipment

Options for instrumentation (monitoring equipment) for both flow and water quality are detailed below.

2.3.3.2 Flow Monitoring Equipment

The following discussion is limited to the most common flow measurements devices and approaches. When selecting an approach or purchasing equipment, pertinent journal articles and equipment vendor listings should be consulted. Proper analysis of typical or expected site discharge conditions is recommended prior to equipment purchase and or installation.

Two (2) general approaches are detailed below:

1. **Absolute method (measured flow):**

   Flow rates and volumes are most accurately measured using either primary of secondary flow measurement devices. This option is more invasive and costly, but does produce absolute flow results.

   A primary device is a man-made control structure inserted into the conveyance system which creates geometric relationship between the depth and the rate of the flow. Typical devices include weirs, flumes and orifices.

   A secondary device is an automated form of rate and volume measurement. Typically a secondary device is used in conjuncture with a primary device to automatically measure flow depth or head. The recorded value is then processed using the established mathematics relationship to relate the depth to flow. Typical devices include floats, ultrasonic transducers, pressure transducers and bubblers.

2. **Non-absolute method (calculated flow)**

   There are a variety of techniques for estimating flow rates which are applicable when primary or secondary devices are not practical or economically feasible. This option is less invasive and costly, but does not produce absolute flow results. However results may be suitable for comparative analysis.

   Non absolute (calculated flow) methods are not as accurate as the absolute methods described above. Typical approach include the float method (velocity x area), the runoff coefficient method (i.e. the rational method) and the slope and depth method (suitable for pipes and ditches). The most commonly used is the slope and depth method which typically assumes a constant pipe slope and the expectation of laminar flow to <u>calculate</u> pipe flow using the Manning equation.

2.3.3.3 Water Quality Monitoring Equipment

The equipment requirements for water quality monitoring will depend primarily on whether sampling will be completed manually or automated, composite or grab. Typically the decision to collect manually or automated is dependent on the frequency of analysis, site location and sampling logistics (overall size of the sampling program and distance between sites). In general grab sampling is typically significantly less costly then automated sampling.

The most comprehensive approach for water quality monitoring includes the use of an automated sampling device installed within a tamper-proof enclosure at the selected outfall site in conjuncture with a flow meter. A flow meter compatible with the selected automated sampling device is utilized to trigger sampling as flow rates change.

For example ISCO, Sigma Hatch and others are manufacturers of common auto sampling devices are used to collect multiple flow proportionate water quality samples (up to 24) throughout the duration of a rainfall event. Many manufactures produce portable devices of similar nature capable of providing up to 48 hours of in-field sample cooling and storage which is important for parameters such as *E.coli* where growth continues and increases as temperatures warm. Such a device is recommended to ensure the preservation of collected samples; however, if budgetary constraints do not favour such model a traditional sampler or equivalent will suffice. Flow meters would record continuous flow data in order to develop the EMC. Recording water levels every 15 minutes is suitable for developing EMCs and loads. The table below summarizes the recommended parameters and sampling procedure.

Water Quality Parameters Sampling & Sampling Procedure

Parameters	Sampling Procedure
Chloride	Automated
E.coli	Automated
Nitrate	Automated
Heavy metals (Copper**,** Lead**,** Zinc**)**	Automated
Total and Dissolved Phosphorous	Automated
Total Suspended Solids (TSS)	Automated
Hardness (as $CaCO_3$)	Automated

2.3.3.4 Rainfall Measurements

In conjunction with water quality and quantity monitoring, the collection of rainfall characteristics and other meteorological parameters may be required (Non -Absolute flow measurements) or simply preferred based on the monitoring objectives. Rainfall measurements provide a permanent record of precipitation and can be use to determine the intensity. The collection of rainfall data is often overlooked as the focus tends to be placed on flow and water quality sites, equipment and results. Carefully consider the monitoring objectives when determining the need for rainfall monitoring.

The collection of rainfall measurements can be accomplished using stations established specifically for the monitoring program or using previously established sites managed by third parties. Data from local gauges maintained by Environment or Navigation Canada, the municipality, agency or institution (university or college) can be utilized at minimal cost provided they are in close proximity to the study area and not under the effect of a separate micro-climate. If a rain gauge site is to be established explicitly for the monitoring program, ensure the site selected is representative of local climate, is not sheltered from the true rainfall pattern and is secure from vandals and thieves. Poor or missing data from a rain gauge site will affect data verification procedure of many, if not all, of the velocity, depth and even water quality monitoring sites.

2.4 Catchment Scale Options

The section below outlines the general options for developing and undertaking catchment scale stormwater monitoring programs, and discusses potential approaches for data collection, considerations for site selection, level of implementation recommended prior to undertaking monitoring and cost estimates for the various options.

2.4.1 General

Catchment based monitoring can cover a wide range of spatial scales (ranging from 100s to 1000s of hectares) and temporal scales (from 1 to 20+ years). While temporal scales of monitoring are generally a function of staff resources and budgets, the spatial scale of catchment based monitoring can include a sewershed, a sub-watershed or watershed and is an important consideration. Studies seeking to understand specific aspect of stormwater impacts based on land use can be done at smaller scales (i.e. site/ property scale – see **Section 2.5**) but to take spatial variability into account (i.e. different soil types, vegetation cover, land uses, human attitudes and behaviors) it is necessary to conduct monitoring at the catchment scale.

2.4.2 General Approaches

Two (2) potential catchment scale monitoring approaches are detailed below, they include:

1. <u>Single Catchment Comparative Approach</u>
2. <u>Paired Watershed Approach</u>

<u>1. Single Catchment Comparative Approach</u>

This approach involves monitoring a singular catchment in two distinct phases:

Phase 1 - Existing catchment condition (pre-LID retrofit)

Phase 2 - Catchment conditions post-LID retrofit

Post monitoring, the catchment is compared and the effectives of the LID retrofits assessed. It must be noted that the time interval between the Phase 1 monitoring and Phase 2 monitoring can be significant (i.e. several years – See **Section 2.4.3** *Level of LID Implementation*) and unforeseen changes within the catchment may occur which may affect the results (road improvements, site redevelopment and or intensification etc.)

<u>2. Paired Watershed Approach</u>

The "paired watershed" approach, as described by Clausen and Spooner (1993), is where two, or more adjacent watersheds or catchments with similar characteristics are monitored simultaneously. One catchment serves as an untreated control while the others represent treated catchments where LID retrofits have been implemented on a widespread basis (i.e. multiple lots). The catchments must have similar characteristics with respect to slope, surficial soil and impervious cover which are primary factors affecting runoff response. Measured totals for such parameters as runoff volumes, peak flow rates, and contaminant loads per hectare of drainage area from each catchment can then be compared on a storm event basis with differences attributed to differences in imperviousness, evapotranspiration and infiltration resulting from the lot level practices. This monitoring approach would be undertaken only when the appropriate level of implementation is reached.

2.4.3 Level of Implementation

In general, regardless of the approach selected (single or paired watershed approaches), the level of LID retrofit will be an extremely sensitive parameter within the overall monitoring program. The following guidelines are suggested (percentages correspond to % of total catchment area) based on previous studies:

- **20% LID retrofit** - is recommended as the absolute minimum level of LID implementation within the monitored catchment area. Below this level measured reductions in flow and improvements in water quality will be difficult to identify. Noise within the collected data will likely cancel out any benefits and statistically valid results will prove difficult.
- **50% LID retrofit –** is an acceptable level of LID implementation within the monitored catchment area. At this level measured reductions in flow and improvements in water quality will be more easily identified and the effect of noise within the collected data will be reduced.
- **80% LID retrofit** – is the preferred level of LID implementation within the monitored catchment area. At this level of implementation, the post LID condition versus the existing condition is more easily validated statistically.

2.4.4 Site Selection

The catchment to be evaluated should be selected based on several criteria including:

1. The catchment should be primarily residential in nature. Inclusion of other land uses (i.e. Industrial, commercial and institutional) does not preclude the catchment area
2. The catchment should be as large as possible so as to minimize local variability, but small enough to permit monitoring at a lower level of implementation. As such a drainage areas of approximate 1 hectare is recommended

3. The catchment should be serviced by one type of drainage system (i.e. storm sewer or ditch system), preferably by storm sewer for ease of sampling
4. The drainage system should accept no external drainage
5. The drainage systems should not have any cross connections with municipal-type sewage systems
6. Areas identified as having high inflow and infiltration (I/I) should be avoided
7. The drainage system should terminate at a single, accessible location
8. The monitoring station should be easy to establish with few of the potential safety problems related to working in manholes or other such structures
9. The boundaries of the catchment area should be well defined.

2.4.5 Cost Estimates

In the past catchment based monitoring program in general have proven difficult to plan, implement and obtain statistically significant results. These programs are also associated with high cost.

Single Catchment Comparative Approach

Assuming a two (2) year program; 1 year of monitoring for the existing condition and 1 year of monitoring for the post LID condition, it is estimated that catchment based monitoring will have an associated cost of $200,000 to $250,000.

Paired Watershed Approach

Assuming a two (2) year program; and two (2) catchments, it is estimated that catchment based monitoring will have an associated cost of $300,000 to $350,000.

2.5 Site Scale Options

The section below outlines the general options for developing and undertaking site scale stormwater monitoring programs, and discusses potential approaches for data collection, considerations for site selection, infrastructure requirements and cost estimates for the various options.

2.5.1 General

Site scale monitoring will cover a much smaller spatial scale as compared to the catchment based approach, with only one residential lot or multiple lots being monitored. The temporal scale of monitoring can range from 1 to 20+ years and is generally a function of staff resources and budgets. The spatial scale (total number of residential lots to be monitored) and the temporal scale of monitoring will generally be determined based on property ownership and or conditional on property access agreements, extent of disturbance and rehabilitation, owner expectations and aesthetic concerns. As such historically, site scale stormwater monitoring is considered to be costly and difficult to implement.

2.5.2 General Approaches

Two (2) monitoring approaches are detailed below, they include:

1. Single Site Comparative Approach
2. Paired Site Approach

1. Single Site Comparative Approach

This approach involves monitoring a singular site in two distinct phases:

Phase 1 - Existing site condition (pre-LID retrofit)

Phase 2 - Site conditions post-LID retrofit

Measured total runoff volumes and peak flow rates for each phase are monitored and then compared on a storm event basis with differences attributed to differences in imperviousness, evapotranspiration and infiltration resulting from the lot level practices.

2. Paired Site Approach

The paired site approach is where two or more adjacent sites with similar characteristics are monitored simultaneously. One site serves as an untreated control while the others represent a treated site where LID retrofits have been implemented. The sites (i.e. residential properties) must have similar characteristics with respect to slope, soil and impervious cover (i.e. house area) which are primary factors affecting runoff response. Measured total runoff volumes and peak flow rates per unit area of drainage area from each site are then compared on a storm event basis with differences attributed to differences in evapotranspiration and infiltration resulting from the lot level practices.

2.5.3 Site Selection

The site to be evaluated should be selected based on several criteria including:

1. The site(s) should be zoned residential, with common zoning designations/ by-laws
2. The site(s) frontage (assumed area of retrofit) should have adequate area for LID retrofits and free of large trees, internal drainage systems, water features, septic systems, sprinkler systems and or added structures (e.g. sheds, pools, patios)
3. The site(s) should accept no external drainage
4. The site(s) should have disconnected downspouts
5. Site(s) with groundwater discharge areas or high groundwater should be avoided
6. House(s) with previous issues relating to foundation seepages, basement flooding and/or excessive dampness should be avoided
7. The site(s) frontage should have uniform slope and no areas of spills or cross-flow
8. The drainage system should terminate at a single location, accessible location
9. The monitoring station should be easy to establish with few of the potential safety problems related to working in manholes or other such structures
10. The boundaries of the site(s) should be well defined

2.5.4 Infrastructure Requirements

Both the Single Site Comparative and Paired Site Approaches (detailed previously) will require significant infrastructure and site alteration to both collect site runoff and accommodate monitoring equipment. Monitoring infrastructure will generally consist of a perimeter collection system and a secure/subsurface monitoring location (See **Figure 1**).

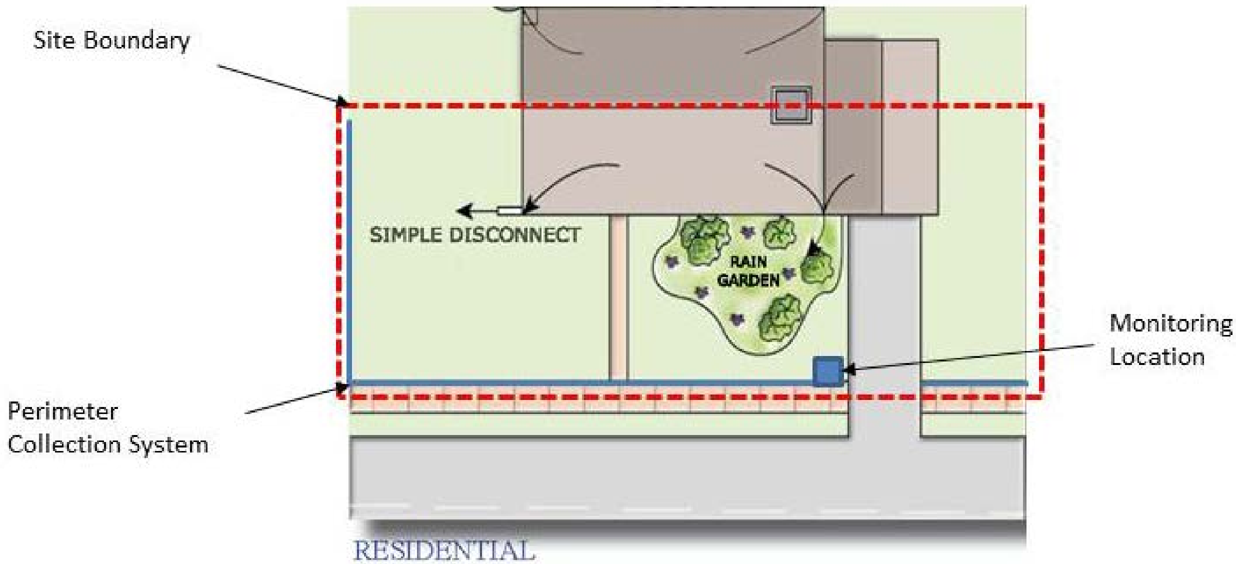

Figure 1 – Conceptual surface runoff collection system and monitoring location

Site scale approaches will require legal agreements with the respective homeowners and generally must include the guarantee of removal the monitoring infrastructure and restoration of the site after monitoring is complete. In addition, compensation may also be offered either monetarily or as site improvements during restoration efforts to gain buy-in during the initial phase.

A potential perimeter surface collection system may include surface troughs, perforated pipes or swales (**Figure 2**). A potential option includes the use of MEA drain system or equivalent. Made from high-quality polymer concrete, these collection systems were developed to allow installation with the minimum amount of effort. These products can support vehicular traffic, should collection of th See Attachment B.

Figure 2 - MEA drain system, model Z1000

Numerous options are available for the type of collection system at the end of the surface system at the proposed monitoring location. Options should be based on monitoring equipment requirements.

If options are selected that lower the invert of the surface drainage systems below the driveway/ adjacent roadway surface, a connection to the subsurface storm system will be required and will significantly increase the cost of monitoring Alternatively, a sump-pump with a float switch can be used to dewater the system during and after events; however an electrical connection is required.

2.5.5 Cost estimates

The infrastructure requirements, legal agreements/liability and the difficulty in obtaining homeowner buy-in for site scale monitoring has proven to be a deterrent by many who wish to undertake such monitoring programs. Site scale programs can generally be implemented at a lower cost than catchment scale monitoring programs.

Single Site Comparative Approach

Assuming a two (2) year program; 1 year of monitoring for the existing condition and 1 year of monitoring for the post LID condition, it is estimated that site based monitoring will have an associated cost of $75,000 plus infrastructure costs. Assuming a standard residential lot area, the perimeter collection system and monitoring location will have an associated cost of $15,000 to $25,000. This does not include costs associated with legal agreements, removal the monitoring infrastructure and restoration or compensation.

Paired Site Approach

Assuming a two (2) year program; and two (2) residential sites, it is estimated that paired site based monitoring will have an associated cost of $75,000 plus infrastructure costs. Assuming two (2) standard residential lot areas, the perimeter collection systems and monitoring locations will have an associated cost of $30,000 to $50,000. This does not include costs associated with legal agreements, removal the monitoring infrastructure and restoration or compensation. The increase in costs is associated with the need for duplicated monitoring infrastructure.

2.6 Desktop Assessment Options

The section below outlines the general options for developing and completing a desktop analysis for residential LID retrofits programs and discusses potential data requirements, parameter selection, and cost estimates for the various options.

2.6.1 General

In general, desktop assessment options are utilized when budgets, staffing and resources do not exist to complete field monitoring programs as detailed in **Sections 2.4** and **2.5**. The results generated through desktop assessment are predictive results which provide an indication of potential performance and therefore benefits resulting from LID retrofits. Nevertheless, the use of desktop assessments can be a valuable tool in analyzing the potential performance of residential LID retrofit programs.

The following sections are not intended to be a comprehensive discussion of desktop assessments and modelling procedures, instead it outlines the potential approaches and specific requirements as it relates to the predictive performance of LID stormwater retrofits for residential lands when in-situ field monitoring cannot be undertaken.

2.6.2 General Approaches

The selection of an appropriate analytical method and/or model will depend on several factors including:

- The type of monitoring project
- Level of detail required - the level of detail required and the various spatial scales.
- The complexity of the analysis i.e. water quality and quantity, event vs. continuous

Some of the most commonly applied analytical methods are discussed in the following section, however, it is recognized that other techniques and models are available and, further, that the analytical methods will continue to evolve over time.

In general, three (3) approaches are outlined below:

1. Spreadsheet based
2. Event based
3. Continuous based

2.6.3 Spreadsheet Based Analysis

Spreadsheet based analysis can be used to estimate both water quality and water quantity performance often using representative values, procedures, relationships and behaviors from literature. The section below provides a brief summary.

2.6.3.1 Spreadsheet Flow Analysis

Typically a spreadsheet based models use the Rational Method to determine flows for smaller drainage areas (such as residential property), within storm sewers or ditch systems.

The Modified Rational Method is expressed as Q=CiA

Where:

Q = Design flow (m^3/s)
C = Runoff coefficient where
i = Rainfall intensity (mm/hr)
A = Contributing drainage area (ha)

2.6.3.2 Spreadsheet Water Quality Analysis

Spreadsheets analysis can be utilized to estimate the characteristics of non-point source (NPS) pollution runoff from residential land uses using Event Mean Concentrations (EMCs). EMCs were developed by the EPA's Nationwide Urban Runoff Program (NURP) (1983) to serve as a national measure of the magnitude of urban runoff, specifically pollutant loadings. Accordingly, the NURP Event Mean Concentrations database or any other EMC databases (i.e. the International BMP database - http://www.bmpdatabase.org/) can be used in conjunction with modest amount of information concerning the hydrology of a site in order to estimate pollutant loadings.

The Simple Method (Schueler, 1987) is one of the common techniques to estimate annual pollutants loads using Event Mean Concentrations (EMCs), drainage areas, impervious cover, and annual precipitation. Pollutant loads are generally estimated for different land use scenarios (e.g. residential) but can also be used to compare between pre-retrofit and post-retrofit conditions. The Simple Method provides a general planning estimate of likely storm pollutant export. More sophisticated modeling may be needed to analyze larger and more complex drainages.

2.6.4 Event Based and Continuous Models

The use of event based and continuous computer models to estimate stormwater flows, volumes and pollutant loadings can be an efficient and cost effective methodology which does not require extensive in-field work or significant staffing. However, modelled results are estimates only and should be used a predictive tool. When modelled flows are calibrated using measured flows, volumes, collected water quality results and rain gauge data confidence is significantly increased.

Some of the most common event based and continuous hydrologic models are listed in **Table 3**.

Table 3 Common Event Based and Continuous Models

Model	Application(s)			
	Event Based	Continuous	Flow	Water Quality
SWMHYMO	◊		◊	
OTTHYMO / VISUAL OTTHYMO	◊		◊	
QUALYMO	◊	◊	◊	◊
GAWSER	◊	◊	◊	
InfoWorks[1]	◊	◊	◊	
PRMS		◊		
SWMM	◊	◊	◊	◊
XP-SWMM	◊		◊	◊
PC-SWMM	◊		◊	◊
HSPF	◊	◊	◊	◊
MIDUSS	◊		◊	

2.6.4.1 Event Based

A single event model simulates the response of a watershed to a short duration rainfall event, typically in the range of 1 hour to 24 hours in length. The rainfall event may be an actual historic storm (e.g. Hurricane Hazel), or a synthetic design storm derived from a statistical analysis of recorded rainfall. Event based models can be used to estimating surface runoff rates, volumes and water quality (see **Table 3**).

2.6.4.2 Continuous Models

A continuous model differs from single event models in that they use a long term time series of historical meteorological data instead of a single storm event. Because they span several seasons, continuous models typically simulate more hydrologic processes than single event models and therefore require considerable more input data from meteorological stations (at a minimum both precipitation and temperature data is required). Continuous modeling is generally conducted with a time series of 15 minutes to 1 hour precipitation intervals available from project specific rain gauges or from a nearby representative gauging station. Depending on the availability of the data and the characteristics of the study area, larger or smaller time steps may be necessary. Depending on the objectives of analysis, the proponent may consider several modeling alternatives:

- distinct historical events modeled back-to-back (i.e., in series)
- an entire year of precipitation, possibly "average", "wet", and "dry" years; or
- multiple years of precipitation covering the period of record for a meteorological gauge site.

In addition to estimating surface runoff rates, volumes and water quality, continuous models may be used to simulate processes such as snow melt and accumulation, evapotranspiration, soil water movement (infiltration) and groundwater recharge.

2.6.5 Cost estimates

Cost estimates for desktop analysis can very significantly depending on the type of analysis (spreadsheets vs. continuous), the availability and quality of existing data, the length of analysis, and the geographic size of the study area etc. However, in general terms spreadsheet analysis is typically the least costly alternative as compared to continuous modeling which represents the most costly option. Desktop analysis is estimated to range from $5,000 to more than $50,000, respectively.

3. Water Use Monitoring Options

3.1 Regional/ Municipal Water Use Billing Options

To assess the effect of LID retrofits on potable water use, an assessment of potable water within a target neighborhood or study area can be completed using a two (2) phase process.

Phase 1 – Collect and Analyze existing potable water use (pre-LID retrofit)

Phase 2 – Collect and Analyze potable water use after LID retrofits have been completed

Potable water use data is collected from the agency responsible for water billing, typically the area municipality or region for a period greater than three (3) years. Multiple years of data is required to provide long-term trends which are stable. Generally, water use information is provided based on type of land use (i.e. residential) according to postal codes. The data types which can be provide include:

- Count of accounts
- Billed consumption separated into quarterly consumption (Q1 – Q4)
- Account details including # of units, schools, churches and apartment buildings

<u>Phase 1 - Existing potable water use (pre-LID retrofit)</u>

Summaries of potable water data can be completed to include:

1. Total water consumption (m^3)
2. Average yearly water consumption (m^3)/quarter
3. Average yearly water consumption (m^3)/quarter/account
4. Total 'winter' and 'summer' water consumption (m^3)

For this analysis it is generally assumed the quarterly data are represented as follows:

- Quarter 1 - January-March,
- Quarter 2 - April-June,
- Quarter 3 - July-September, and
- Quarter 4 - October-December.

It is important to confirm this assumption with the data provider prior to undertaking the analysis.

The data within Phase 1 will represent baseline values that will be used to evaluate the effectiveness of Low-Impact Development (LID) retrofits using water efficient landscaping

/plants at reducing potable water use during summer months. Future efforts in this regard will be evaluated against this baseline data.

An example which demonstrates the Phase 1 (Existing potable water use pre-LID retrofit) in the Town of Alton has been completed and is included as **Attachment A**.

<u>Phase 2 – Potable water after LID retrofits</u>

Phase 2 will represent the post LID retrofit using water efficient landscaping /plants. Replicate data (as detailed above) should be acquired from the agency responsible for water billing and the analysis repeated. Recommendations in this regard are summarized below:

- The Phase 2 data set should represent potable water use <u>after</u> plant establishment as water usage generally increase after planting until plant fully establish due to irrigation needs. A minimum of one (1) year separation is recommended.
- The data set should span a minimum of three (3) years;
- The analysis should include a review of any Regional or Municipal water efficiency programs such as low-flow fixture and/or appliance rebate programs etc. Parallel programs may affect the resulting analysis and conclusions.

3.2 Site Scale Water use Monitoring Options

Potable water use monitoring can also be undertaken at the site scale itself. Using this approach, water use in measured and recorded using flow metering equipment attached to the potable water supply line of the water meter itself. Using this approach, actual water use can be directly measured. The approach, as detailed above would require a comparison of potable water use pre-LID retrofit vs. post LID retrofit.

Alternatively, using an informations haring agreement between the homeowner and the municipality, region of agency who wished to perform the monitoring, direct reporting from the residents to the on their water use (m^3) per billing period could be completed. Privacy agreements would likely be required and data security may not be entirely possible.

In either case, it is recommended that a log-book be completed which documents any variable that may influence potable water use such as new appliances, toilets, or low flow fixtures etc.

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Attachment A – Potable Water Summary (2005-2011) Existing Conditions

1. Introduction and Methodology

Water-use data obtained for the Village of Alton contained quarterly Billed Water Consumption (m^3) data for each Postal Code within Alton over the years 2005-2011. **Figure 1.0** illustrates the Town of Alton, property boundaries, and associated postal codes.

Billed consumption for each quarter were separated into residential and industrial accounts, the number of accounts within each postal code being provided for each recorded year.

The data were summarized for both residential and industrial accounts as follows:

1. Total water consumption (m^3) within Alton from 2005-2011;
2. Average yearly water consumption (m^3)/quarter between 2005-2011;
3. Average yearly water consumption (m^3)/quarter within each postal code between 2005-2011;
4. Average yearly water consumption (m^3)/quarter/account within each postal code between 2005-2011; and
5. Total ‘winter’ and ‘summer’ water consumption (m^3) from 2005-2011 for each postal code.

For this exercise, it was assumed the quarterly data are represented as follows:

- Quarter 1 - January-March,
- Quarter 2 - April-June,
- Quarter 3 - July-September, and
- Quarter 4 - October-December.

Two postal codes were omitted from the analysis: L0N1A0 was located outside of Alton Village and therefore not included in the analysis; O0O0O0 is an amalgamation of postal codes which had only one account. As their locations could not be verified, they were omitted from the analysis.

These data represent baseline values that will be used to evaluate the effectiveness of Low-Impact Development (LID) retrofits using water efficient landscaping /plants in accordance with the Fusion Garden Program at reducing potable water use during summer months. Future efforts in this regard will be evaluated against this baseline data for the Village of Alton.

Figure 1.0

2. Results (Baseline Data)

2.1 Total Yearly Water Consumption

Figure 2.1 and Figure 2.2 show the total water consumption (m^3) for all residential and industrial postal codes respectively between the years 2005-2011. These figures show that total water consumption generally decreased within Alton between the years 2005-2011.

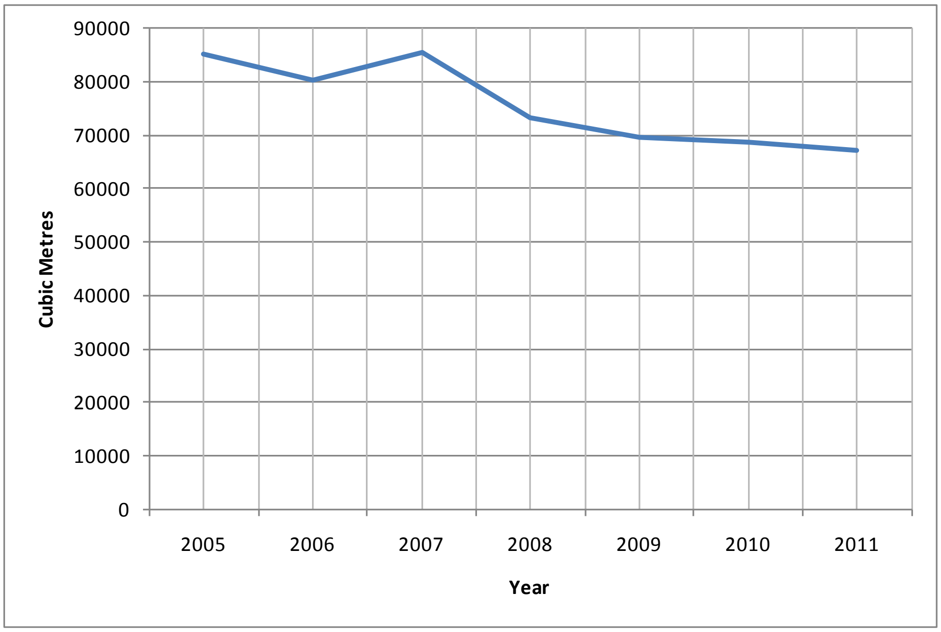


Figure 2.1: Total residential water consumption (m^3) across all postal codes for each year between 2005-2011.

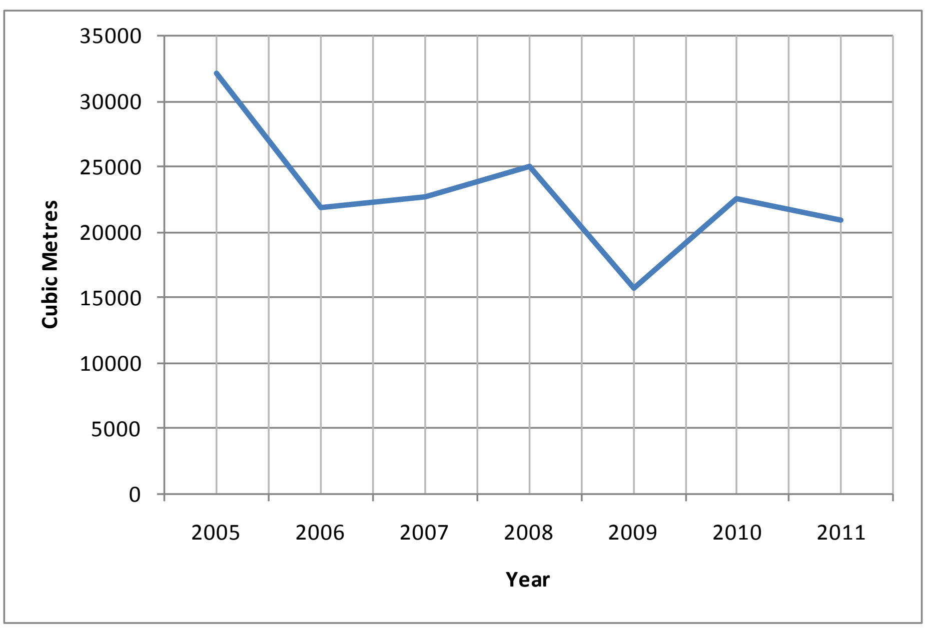


Figure 2.2: Total industrial water consumption (m^3) across all postal codes for each year between 2005-2011.

2.2 Quarterly Water Consumption

The yearly average quarterly water consumption (m^3) from 2005 to 2011 for both residential and industrial postal codes is shown in Figure 2.3 and Figure 2.4 respectively. These figures show that average quarterly consumption generally increased in the second and third quarter before dropping in the fourth quarter. Industrial quarterly water consumption results within postal code L7K0C4 is presented in Figure 2.5. Water consumption within this postal code was an order of magnitude greater than all other postal codes combined. To avoid skewing the results, results for this postal code were analysed separately. Figure 2.5 shows that water consumption within industrial postal code L7K0C4 continues to increase throughout the third and fourth quarter. This is inconsistent with other industrial postal codes which show a decrease in consumption during the fourth quarter.

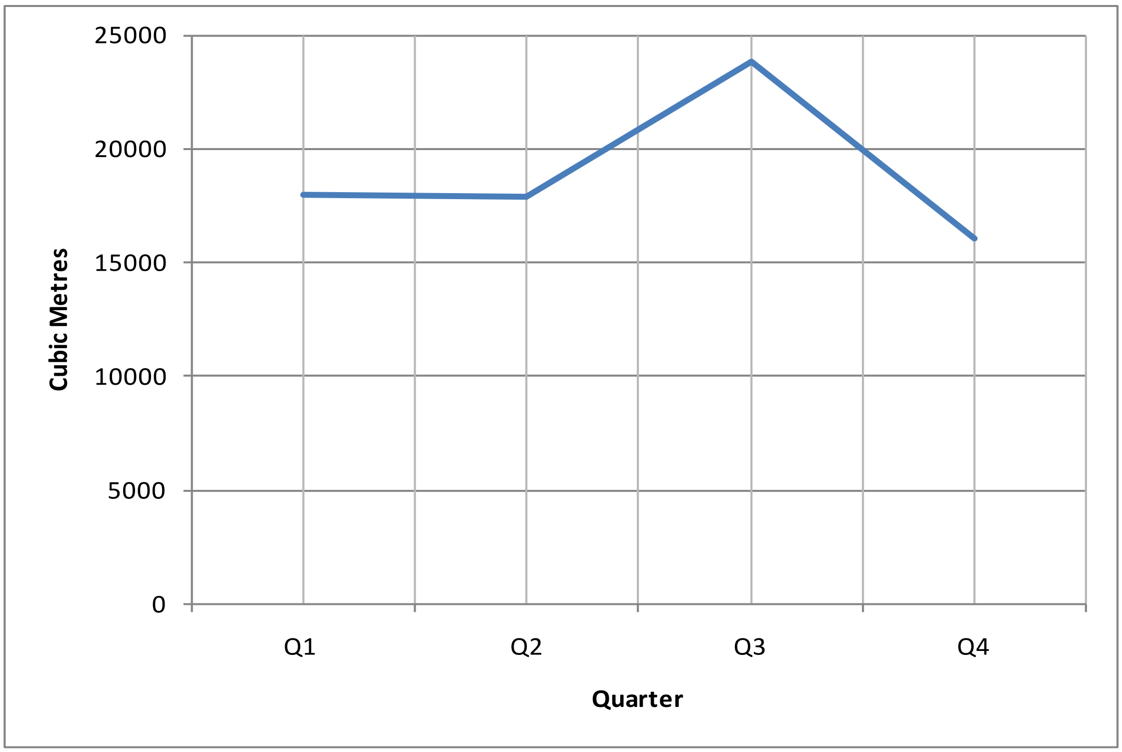


Figure 2.3: Yearly average quarterly water consumption (m^3) for residential postal codes from 2005-2011

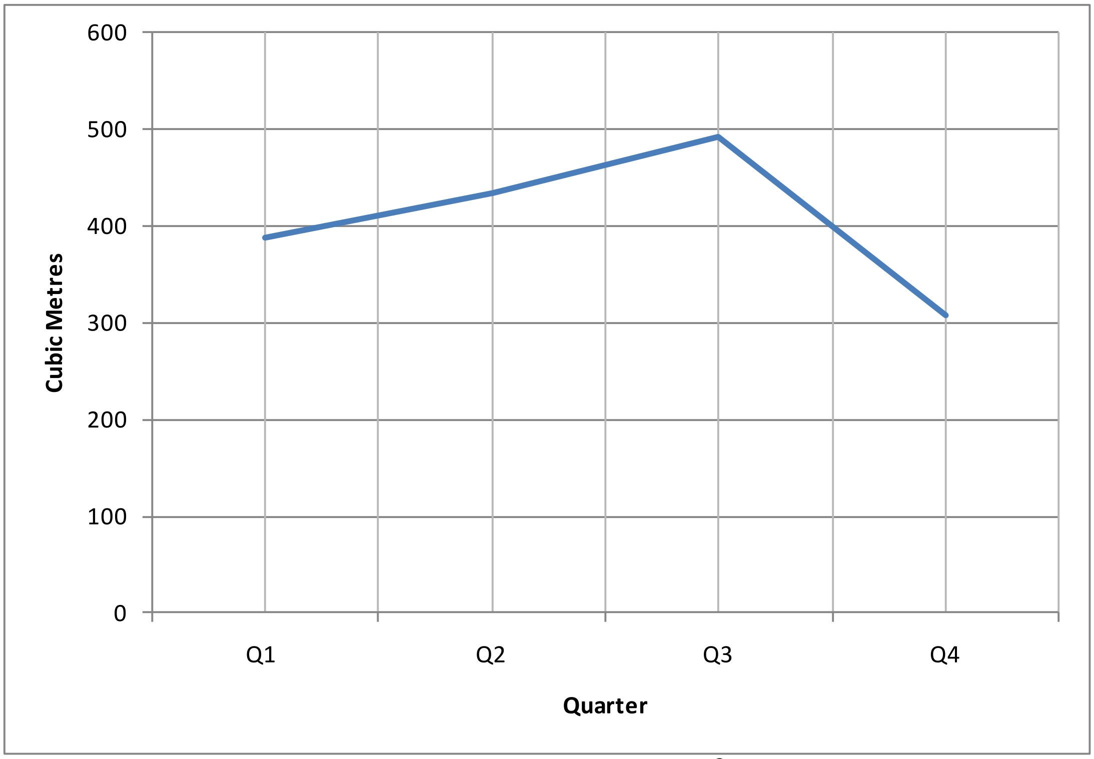


Figure 2.4: Yearly average quarterly water consumption (m^3) for industrial postal codes from 2005-2011.

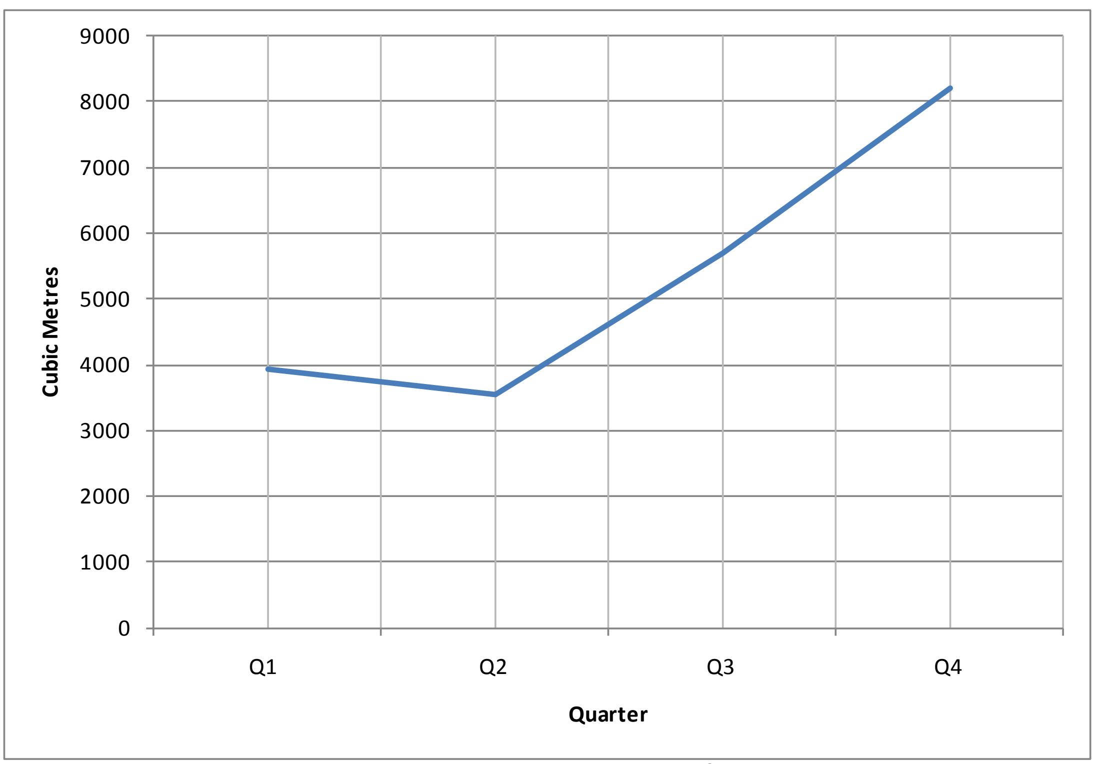


Figure 2.5: Yearly average quarterly water consumption (m^3) for industrial postal code L7K0C4 from 2005-2011.

Table 2.1 and Table 2.2 show the average yearly water consumption values for residential and industrial postal codes respectively from 2005 to 2011. Additionally, the average yearly water consumption values were calculated for each individual account by dividing the total quarterly consumption value for each postal code by the number of accounts within that postal code in any given year.

Table 2.1: Residential Average Yearly Water Consumption (m^3) per Quarter

	Average Yearly Consumption (m^3)				Average Yearly Consumption (m^3) per account			
Postal Code	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**
L7K0C2	1708.6	1678.6	2550.0	1548.6	55.5	54.4	82.7	50.2
L7K0C3	608.6	551.4	715.7	595.7	50.7	46.0	59.6	49.6
L7K0C4	1465.7	1462.9	1898.6	1272.9	54.3	54.2	70.3	47.1
L7K0C5	1664.3	1551.4	1980.0	1457.1	55.5	51.7	66.0	48.6
L7K0C6	2478.6	2367.1	2972.9	2135.7	67.0	64.0	80.3	57.7
L7K0C7	2300.0	2361.4	3300.0	2048.6	67.6	69.5	97.1	60.3
L7K0C8	1371.4	1304.3	1827.1	1252.9	62.3	59.3	83.1	56.9
L7K0C9	2470.0	2572.9	3337.1	2180.0	65.0	67.7	87.8	57.4
L7K0E1	607.1	570.0	878.6	520.0	70.1	65.9	102.0	60.4
L7K0E2	1462.9	1450.0	1821.4	1330.0	56.3	55.8	70.1	51.2
L7K0E3	951.4	1008.6	1371.4	872.9	52.9	56.0	76.2	48.5
L7K0E4	542.9	667.1	651.4	485.7	45.2	55.6	54.3	40.5
L7K1P7	182.9	190.0	277.1	188.6	35.0	36.2	52.4	35.9
L7K1R4	145.7	155.7	220.0	132.9	72.9	77.9	110.0	66.4

Table 2.2: Industrial Average Yearly Water Consumption (m^3) per Quarter

	Average Yearly Consumption (m^3)				Average Yearly Consumption (m^3) per account			
Postal Code	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**
L7K0C2	101.4	110.0	158.6	87.1	33.8	36.7	52.9	29.0
L7K0C4	3920.0	3532.9	5708.6	8208.6	1054.2	926.0	1501.4	2218.6
L7K0E1	180.0	194.3	221.4	112.9	60.0	64.8	73.8	37.6
L7K0E4	105.7	130.0	112.9	108.6	52.9	65.0	56.4	54.3

2.3 'Winter' versus 'Summer' Water Consumption

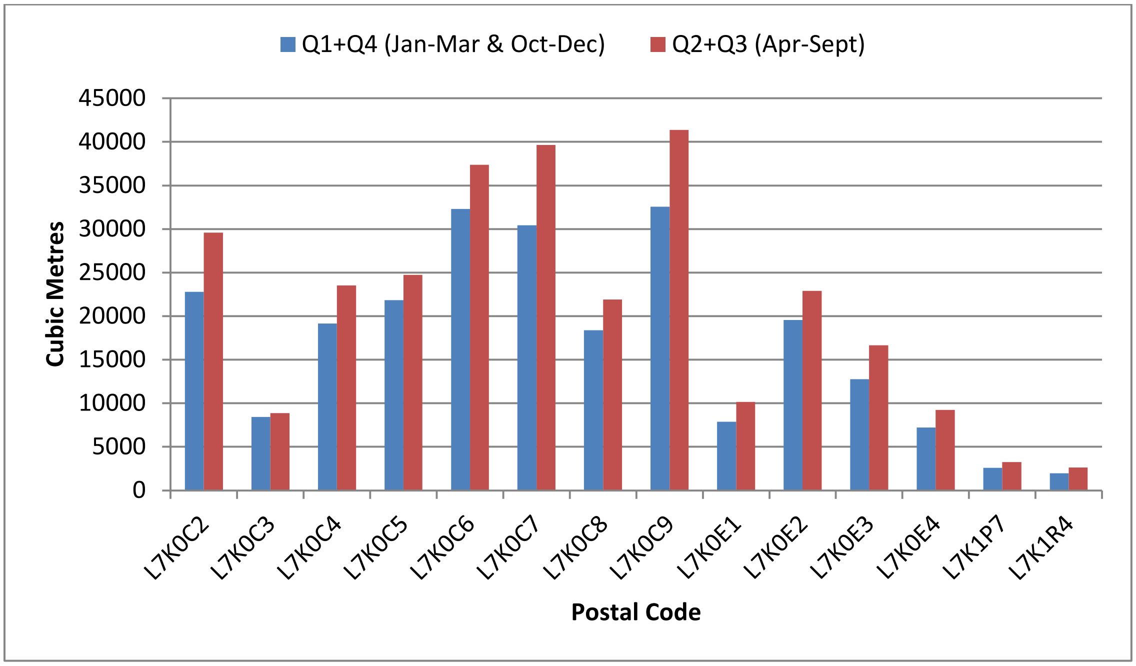
As stated in Section 1.0, it was assumed for this exercise that Quarter 1 represents the months of January-March, Quarter 2 April-June, Quarter 3 July-September, and Quarter 4 October-December. To compare winter and summer water consumption values over the seven year period from 2005-2011, Quarter 1 and Quarter 4 were combined to represent total winter consumption and Quarter 2 and Quarter 3 were combined to represent total summer consumption (when outdoor water use is expected to be at its highest). Total consumption values for each residential and industrial postal code between 2005-2011 are presented in Table 2.3. Figure 2.6 illustrates the average yearly water consumption values for residential postal codes in the second and third quarter (April to September).

Table 2.3: Total Residential and Industrial Water Consumption Values for each Postal Code between the Years of 2005-2011. Consumption values are separated into 'summer' and 'winter' months. The absolute and % increase during the summer months is also shown.

Residential				
	Total Consumption (m^3) (2005-2011)			
Postal Code	**Q1+Q4**	**Q2+Q3**	**Increase (m^3)**	**% Increase**
L7K0C2	22800	29600	6800	23
L7K0C3	8430	8870	440	5
L7K0C4	19170	23530	4360	19
L7K0C5	21850	24720	2870	12
L7K0C6	32300	37380	5080	14
L7K0C7	30440	39630	9190	23
L7K0C8	18370	21920	3550	16
L7K0C9	32550	41370	8820	21
L7K0E1	7890	10140	2250	22
L7K0E2	19550	22900	3350	15
L7K0E3	12770	16660	3890	23
L7K0E4	7200	9230	2030	22
L7K1P7	2600	3270	670	20
L7K1R4	1950	2630	680	26
Industrial				
	Total Consumption (m^3) (2005-2011)			
Postal Code	**Q1+Q4**	**Q2+Q3**	**Increase (m^3)**	**% Increase**
L7K0C2	1320	1880	560	30
L7K0C4	84900	64690	-20210	-31
L7K0E1	2050	2910	860	30
L7K0E4	1500	1700	200	12

Between the years of 2005-2011, residential water consumption increased in the second and third quarter (April to September) by an average of 19%. When omitting industrial postal code L7K0C4 from the analysis, industrial water consumption increased in the second and third quarter by an average of 24%. As shown in Figure 2.5, yearly average water consumption increases in the fourth quarter at industrial postal code L7K0C4.

Figure 2.6: Residential Average Yearly Water Consumption (m^3) per Quarter



3. Conclusion

It will be the object of Phase 2 of the monitoring program to compare the baseline values (second and third quarter - April to September) to evaluate the effectiveness of Low-Impact Development (LID) retrofits using water efficient landscaping /plants in accordance with the Fusion Garden Program at reducing potable water use during summer months.

Attachment B – MEA DRAIN