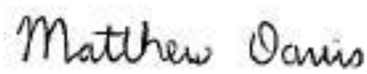
Contaminant Load Model User Manual

September TR 2010/003

Auckland Regional Council
Technical Report No.003 September 2010
ISSN 1179-0504 (Print)
ISSN 1179-0512 (Online)
ISBN 978-1-877540-50-9

Technical Report, first edition.

Reviewed by:	Approved for ARC publication by:
	
Name: Judy-Ann Ansen	Name: Matthew Davis
Position: Acting Team Leader Stormwater Action Team	Position: Group Manager Partnerships & Community Programmes
Organisation: Auckland Regional Council	Organisation: Auckland Regional Council
Date: 12 September 2010	Date: 18 September 2010

Recommended Citation:

Auckland Regional Council (2010) Contaminant Load Model User's Manual. Auckland Regional Council Technical Report TR2010/003.

Contaminant Load Model User Manual

Prepared for
Auckland Regional Council

Contents

1 **Executive Summary** 3

2 **Introduction** 4

2.1 Overview of the manual 5

3 **Model application and qualifications** 6

3.1 Intended application 6

3.2 Application to small catchments 6

3.3 Application to places other than Auckland 7

3.4 Application to rural land uses 7

3.5 Application as a design tool 7

4 **Accuracy of calculated loads** 9

4.1 Source areas 9

4.2 Source yields 12

4.3 Management option trains 13

4.4 Load reduction factors (LRF) 13

5 **Model spreadsheet** 15

This chapter provides details of the model spreadsheet, including the method for calculating annual contaminant loads and an explanation of the spreadsheet content. 15

5.1 Method of calculating annual loads 15

5.2 Spreadsheet cells 15

5.3 Compulsory input data 16

5.4 Optional input data 16

5.5 Default data 17

5.6 CLM results output 17

5.7 Results interpretation 18

6 **Complex sites: A worked example** 20

6.1 General 20

6.2 The hypothetical site 20

6.3 Site source areas 20

7 **References** 33

Appendix A: Model inputs **34**

A.1 Source areas 34

A.2 Management options 38

A.2.1 Fraction draining to management option train 39

A.2.2 Load reduction factors 39

Appendix B: Source yields **43**

Appendix C: Load reduction factors **45**

1 Executive Summary

In order to assess the environmental effects of stormwater discharges, information about the nature and quantity of the contaminants that they contain is required. Stormwater quantity and quality can be highly variable and challenging and resource-intensive to monitor. A pragmatic solution is to model contaminant discharges based on information derived from observations of stormwater quality.

The Contaminant Load Model (CLM) is a spreadsheet-based model which has been developed to enable estimation of stormwater contaminant loads on an annual basis. The model is very simple in principle - the area of a particular land use (source) within the area being studied (the catchment) is multiplied by the quantity of contaminants discharged from that land use (source yield) to provide an annual load from that source. The loads from each source within the catchment are then added together to provide an annual contaminant load for the catchment of interest.

The CLM incorporates six urban land use types (sources), these being roofs (divided into nine different types of material); roads (divided into six different vehicles/day categories); paved surfaces, other than roads and roadside footpaths (divided into residential, commercial and industrial); urban grasslands and trees (divided into three different slope categories); urban streams; and construction sites (considered to be 100% bare earth for the purposes of estimating contaminant loads). Although it has been developed for urban stormwater discharges, the CLM also incorporates five rural land uses, each subdivided into three categories, to enable mixed land use catchments around the fringes of the Auckland urban area to be modelled.

Source yields from the different source areas are provided for Total Suspended Solids (TSS), zinc (Zn), copper (Cu) and Total Petroleum Hydrocarbons (TPH).

A further consideration in modelling contaminant loads is any stormwater management or treatment that is implemented to reduce the loads of contaminants discharged to receiving water bodies. These are generically represented in the model by load reduction factors (LRF), and can include a range of options from source control to stormwater treatment devices.

The first version of the CLM was made available for general use in January 2006 and a modified version currently in use was issued in May 2006. A new version, Version 2, has been made available with the release of this report (CLM Users Manual) and the CLM Development Report. The new version includes improved model parameter values and the option for users to enter their own load reduction factors (these were fixed at default values in the previous versions of the model).

This users manual provides guidance on how to use the CLM model. It explains the required and optional model inputs, the model outputs, how to use the outputs, how to apply the model to complex sites and the factors affecting the accuracy of the calculated loads. The development of the model is described in an accompanying report (Timperley et al, 2010).

Acknowledgements

The Contaminant Load Model (CLM) and supporting reports were funded by the Auckland Council and the legacy Auckland Regional Council under the Stormwater Action Plan. Dr Mike Timperley, Auckland Regional Council Stormwater Advisor, is the principal author. Melanie Skeen and Rajika Jayaratne assisted Dr Timperley with portions of the manuscript. Jonathan Moores, National Institute of Water and Atmospheric Research, contributed to incorporating peer review comments into the final document and provided overall content review.

The CLM and reports were subject to internal officer and international peer review. The international review was undertaken as part of the assessment of the Central Waitemata Harbour and Southeastern Manukau Harbour / Pahurehure Inlet contaminant studies.

Technical oversight and direction were provided by Dr Judy-Ann Ansen, Stormwater Technical Services Manager and Matthew Davis, Manager of Development and Technical Services of the Stormwater Unit.

2 Introduction

The Contaminant Load Model (CLM) was developed as a tool for estimating the annual loads of contaminants discharged from stormwater networks serving large areas of mixed urban land use, including up to a maximum of 20% of rural land. The contaminants included in the model are: total suspended solids (TSS), total zinc (TZn), total copper (TCu) and total petroleum hydrocarbons (TPH).

This user manual provides guidance on how to use the CLM model. It explains the required and optional model inputs, the model outputs, how to use the outputs, how to apply the model to complex sites and the factors affecting the accuracy of the calculated loads. The development of the model is described in an accompanying report (Timperley et al, 2010).

Catchment size and areas of each source within a catchment are the minimum required inputs to the model. With these inputs the model outputs are the unmanaged (no stormwater management options i.e. quality treatment) annual loads of TSS, TZn, TCu and TPH for each source category. These are referred to as uncontrolled loads. The model also estimates the average annual catchment yields in kg ha^{-1} $year^{-1}$. The optional inputs to the model are the stormwater management options, for example stormwater treatment methods to reduce contaminant loads.

Further model inputs are load reduction factors (stormwater treatment device efficiencies) that the user may wish to use in place of the default values in the model. The model outputs in this case are the unmanaged and managed annual loads for each source category.

2.1 Overview of the manual

The manual is organised as follows:

Chapter 1 provides a general overview of the model's approach;

Chapter 2 presents the model's intended application and qualifications;

Chapter 3 provides details of the spreadsheet model utilised. This chapter also provides model outputs and how to interpret the simulated results;

Chapter 4 applies the model step by step to a complex hypothetical catchment;

Chapter 5 discusses uncertainties in the model parameters, their origins and how to reduce errors in predicted results;

Appendix A: Input data;

Appendix B: Source yields;

Appendix C: Load reduction factors.

3 Model application and qualifications

3.1 Intended application

The primary purpose of the CLM is to provide a basis for estimating stormwater contaminant loads discharged from a stormwater network serving large catchments of urban land use. In general, the larger and more diverse the urban area, the more reliable will be the load estimates.

Complex catchments, for example, with multiple management options for different parts of the same source area, can be modelled by creating several virtual catchments so that the source areas in each virtual catchment have only one management option. The sub catchments are "virtual" because they do not necessarily exist on the ground, although the sums of the virtual source areas equal the source areas in the original catchment. Each virtual sub catchment is modelled with a separate spreadsheet and the sub catchment loads are summed to produce the loads for the original catchment. A worked example of this is provided in Section 5.

Assessing the effects of stormwater contaminants on aquatic life requires annual catchment loads for future years. Although some guidance is given below on what matters need to be considered when modelling future years, model users are in the best position to know what future land use changes are planned and should make the corresponding changes to source areas.

It should be noted that the CLM produces only the contaminant loads; it does not assess the effects of these loads on receiving environments. The CLM can be used to compare the contaminant loads with and without the designed treatment. This comparison is a sensible inclusion in an Integrated Catchment Management Plan (ICMP), but for assessing effects, particularly in coastal marine areas, additional steps will be necessary. For example, the loads estimated by applying the CLM can be used as inputs to other models which predict the fate of contaminants in the receiving environment (see, for instance, Green et al., 2008).

3.2 Application to small catchments

The CLM can be applied to small catchments (less than 20ha), but the validity of the reference area fractions, if these are used to estimate source areas, and the contaminant yields for paved surfaces, must be confirmed.

The reference source area fractions provided to estimate source areas when these areas are unknown (see Appendix A), become increasingly unreliable as the catchment area decreases. For catchments smaller than 20 ha, the model user must confirm the validity of the reference source area fractions, for example by comparing the catchment characteristics to those of Auckland City's urban area , before using the reference fractions to estimate source areas. If there is any doubt about the validity of the reference fractions, then the source areas should be estimated by other means, for example aerial photography, development plans or a site survey.

The contaminant yields used in the CLM for roofs, roads and pervious surfaces are valid irrespective of the total area of the catchment being modelled. For example, each m^2 of unpainted galvanised steel roof will produce the same amount of zinc irrespective of whether the catchment is small with only one house, or large with 10,000 houses. Similarly, an "average" vehicle will leave the same average amount of zinc on the road from tyre wear irrespective of whether the catchment is small with 0.5 km of road or large with 100 km of road. The amounts of TSS produced by pervious surfaces in the model are also reasonably independent of the size of the site.

The yields for paved surfaces were derived from the model calibration. For more details on this refer to Section 7 in the CLM Development Report (Timperley et al., 2010). The contaminant loads produced by paved surfaces incorporate the "true" paved surface loads plus the errors in the loads for all other sources. Therefore model users should be aware that resulting loads of contaminants produced by these surfaces apply only to sites of similar size and complexity to the calibration catchments (Section 7, Timperley et al., 2010). It is these yields that make the CLM generally inapplicable to small catchments, particularly if those catchments contain large area proportions of industrial development. The errors that can arise in the calculated loads for small catchments are explained in Section 4.

The success of applying the model to small catchments depends on the model user having a clear understanding of both the sources of contaminants in the catchments and the CLM.

3.3 Application to places other than Auckland

The CLM model was first made available in January 2006 to help with the development of ICMPs throughout the Auckland region. It has also been used in other parts of New Zealand, though with limited success, mainly because the yields for TSS are unlikely to be correct for rainfall and soils different from those in Auckland. The only solution to this is to obtain TSS yield data from either monitoring or modelling for the intended area of application. The generation of chemical contaminants predicted in the CLM should, however, be reasonably applicable to most urban areas of New Zealand. Where local data on stormwater quality are available, the applicability of the CLM can be assessed by comparison of those data with the annual mean concentrations presented in Section 8.2 of Timperley et al., 2010.

3.4 Application to rural land uses

Relative to similar areas of urban land, rural land generates negligible quantities of zinc, copper and TPH, but can contribute substantial quantities of TSS due to pervious surfaces. The CLM has not been calibrated for catchments containing rural land. This means that the TSS loads estimated by the CLM for such catchments will be more uncertain than will be the loads estimated for fully urban catchments. In order to minimise this error for catchments containing both urban and rural land, the CLM model should only be applied to areas where the total area of rural land is less than about 20% of the total catchment area.

3.5 Application as a design tool

Some users have assumed that the CLM is a design tool able to replace relevant stormwater engineering education and experience. This is not the case and the CLM does not provide any guidance for selecting suitable stormwater management options (treatment devices) for a particular catchment. The selection of the best management options must be made by applying sound stormwater engineering principles to the catchment characteristics, including the hydrology and the sources, types and forms of the contaminants to be managed. As a first point of reference, readers are directed to Auckland Council's TP10 Guidelines for the design of stormwater management devices (ARC, 2003).

Once management options that are appropriate for the catchment have been selected on the basis of these principles, then the CLM can be used to estimate the resulting catchment loads in order to evaluate the overall effectiveness of the management options selected, and to provide load data for input to the receiving environment assessment.

4 Accuracy of calculated loads

The accuracy of the calculated loads is determined by the uncertainties in the model parameters. It is important that users are familiar with these sources of uncertainty in order to appreciate the level of accuracy of model outputs. In particular, model accuracy is influenced by:

- differences between reference source area fractions and actual source areas in a given study area;
- uncertainty in source yields; and
- uncertainty in LRFs for different treatment devices and the inability of LRFs to reflect the sequencing of treatment devices in a treatment train.

Timperley et al. (2010) examined the influence of uncertainty in the source area fractions and source yields by varying model input parameters within specified ranges. Modelled contaminant loads were found to vary by ± 20% for TSS, ±35% for total zinc and ± 25% for copper. While these ranges are not hard and fast measures of the accuracy of CLM, they do provide an indication of the general level of uncertainty associated with the model outputs.

These areas of uncertainty, their origins and how the model user can reduce them are explained in the following sections.

4.1 Source areas

If source areas are known then the CLM will produce loads with accuracy limited only by the uncertainties in the source yields and load reduction factors. By far the largest errors in the loads occur when some source areas are not known and the reference source area fractions determined during model development (Timperley 2010) are inappropriate for the particular catchment being modelled.

The reference area fractions (Appendix A) are unlikely to be exactly correct for any catchment, so it should be assumed that uncertain loads will always be produced by use of the reference fractions to estimate source areas. In general, the larger the catchment and the more similar it is in character to the urban areas of Auckland City from which the fractions were derived, the more accurate will be the calculated loads. The limitations of these reference fractions must be recognised by the model user and it is his/her responsibility to decide from knowledge of the urban area to be modelled if the default area fractions will be valid. Where this is not the case, consideration should be given to accurately measuring source areas for the study area in question, for instance from GIS analysis of aerial photographs and other relevant shapefiles.

The most common situations that lead to excessively erroneous loads from use of the reference area fractions area are described in the following sections.

4.1.1 Roof materials

Galvanised steel, where it is still present on more than about 5% of building roofs, is the largest contributor to zinc loads in roof runoff, and copper sheet is the only significant contributor to copper loads in roof runoff. Substantial deviations of the actual areas of these materials in a particular catchment from those determined using the reference area fractions will lead to highly erroneous catchment zinc and copper loads.

The most rapid change in roof materials that has already occurred in many older urban areas is the replacement, subsequent to 1995, of galvanised steel roofing with aluminium/zinc coated steel (this new material was introduced by NZ Steel Ltd in 1994). The reference area fractions were derived from a mix of catchments in ACC that had undergone various degrees of redevelopment. The average extent of redevelopment across this mix of catchments was however relatively minor, as is indicated by the substantial average proportions of galvanised steel on existing roofs in the areas surveyed, i.e. residential 27.8 %, commercial 36.7% and industrial 91% (Timperley et al., 2010).

If the model user knows that extensive replacement of galvanised steel has taken place, or large part of the catchment was developed after 2000, then the reference area fractions for roof materials should be altered to reduce the fraction of galvanised steel and increase the fraction of aluminium/zinc coated steel (NOTE: The calculation of source areas using the reference area fractions is done outside the CLM, Timperley et al., 2010). Apart from this, reference area fractions will be sufficiently reliable through to about 2020 under following conditions.

1. For urban areas developed before 2000 that have not already undergone extensive redevelopment
2. For urban areas unlikely to undergo extensive redevelopment within the foreseeable future

Copper sheet is not widely used on residential building roofs, presumably because of its high cost. Therefore, reference source area fraction will be reasonable to use for copper sheet roofs. The situation where the reference area fraction for copper roofs might not be valid is where a small catchment has, or will have, one or more substantial commercial or public buildings with copper roofs. Therefore, the model user should be aware of such situation from either the development plans for a new catchment, or from visual inspection of an existing catchment.

4.1.2 Roads

Large lengths of motorways in particular, but also arterial roads, invalidate the reference area fractions for the road vpd categories. This situation is easily recognised and the reference area fractions can be altered accordingly. The motorway area can usually be obtained from GIS.

4.1.3 Paved surfaces

The area of paved surface is not directly a major issue for the intended application of the CLM, but the contaminant yields for paved surfaces were derived from the CLM calibration. The true paved surface yields are unknown, and are bundled together with the errors in all the other source yields. These yields, therefore, have maximum validity only for large urban catchments with area proportions around 10% to 30% of paved surfaces, similar to those in the calibration catchments.

As the area proportion of paved surfaces increases, errors in the paved surface yields have an increasing influence on the calculated loads. This influence can be minimised by ensuring that the area of paved surfaces is a small fraction of the total catchment area.

The influence of the paved surface yields on the accuracy of the calculated loads is explained in Section 3.2.2.

4.1.4 Construction sites and streams

Construction sites and urban streams have high yields for TSS, although for large urban catchments the areas of both construction sites and urban streams are usually quite small. If it is known that a catchment has no active construction or no streams then the areas of these can be set to zero. Conversely, if a catchment has a large amount of bare earth on construction sites, then the areas of these sources should be increased. The area of urban grasslands and trees should be either increased or decreased to balance the changes made to the areas of construction sites and streams. These changes would improve the accuracy of the TSS loads, but would have little effect on the total zinc and total copper loads.

4.1.5 An example of inappropriate reference source areas application

The errors that can arise in the calculated loads from inappropriate application of the reference area fractions have been mentioned above. The following example illustrates these errors.

Of the eight stormwater catchments included in the ACC/Metrowater stormwater monitoring programme, coincident quality and discharge data were successfully captured for only four catchments. Three of these catchments were used for calibrating the CLM (Timperley et al., 2010). The annual stormwater contaminant loads for the Orakei catchment were determined from the stormwater monitoring data using the same accumulation/washoff model that was used for the Mission Bay catchment (Timperley et al, 2004).

The Orakei catchment is very close to the Mission Bay catchment. Both of these catchments are 100% residential but the character of their stormwater networks appears to differ in that the network in the Orakei catchment has no obvious sections of exposed stream channel above the sampling site.

The source areas, e.g. roofs, roads, etc, have not been measured for the Orakei catchment, so the only option for obtaining the source areas is to use the residential reference area fractions in Table A.2.

The results obtained (without any adjustments to the reference area fractions to allow for known characteristics of the Orakei catchment), are compared to the stormwater loads determined from the monitoring data in Table 1. The loads compare well for copper but the loads calculated with the CLM for TSS and total zinc are about twice the loads determined from the catchment stormwater monitoring data. These differences reflect the extent to which the source areas of the Orakei catchment differ from the areas calculated using the reference area fractions for residential land use.

The following catchment characteristic variations noted.

1. The Orakei catchment stormwater network has no apparent open stream channel above the sampling site.
2. The population increase between 2001 and 2006 was 38 people or about 7.6 persons per year. This is equivalent to 2.5 dwellings or about 380 m^2 of construction site bare earth (Chapter 4, Timperley et al., 2010).
3. The Orakei catchment is a high value residential area similar in character to Mission Bay with many of the original galvanised steel roofs now replaced with other materials.

Therefore, the area fractions can be changed as follows for the Orakei catchment:

1. The stream area can be set to zero
2. The construction site area can be set to 380 m^2

3. The total area proportion of galvanised steel roofs can be reduced to 10.6% (of total roof area) as in the Mission Bay catchment but with the same distribution of surface condition, i.e. unpainted, poorly painted and well painted (Chapter 4, Timperley et al., 2010).

The CLM loads with adjusted area fractions shown in Column 4 in Table 1.

TSS load is now closer to, but still about 30% higher than, the load determined from the monitoring data. A ground-level inspection of the Orakei catchment would be the only way to identify other adjustments to the area fractions that would deduce this difference. Ideally, of course, this inspection would be done as a normal pre-cursor to applying the CLM.

The zinc load is also higher than the load determined from the monitoring data. It is probable that this is due to smaller areas of galvanised steel roofs than the 10.6% of roof area that was measured for Mission Bay. There is no method of confirming this other than a survey of roof areas and materials in the Orakei catchment. The copper load remains effectively the same as the load determined from the monitoring data.

The differences shown in Table 1 highlight the potential errors that can arise from application of the reference area fractions to urban areas that differ substantially in character from the assumed "average" urban area. It should be noted that the Orakei catchment of 54.7 ha is small relative to most of the urban areas for which ICMPs are prepared. As an urban area increases in size, it is likely to become more diverse and the reference area fractions are more likely to reflect the actual catchment source areas.

Table 1. Annual stormwater contaminant loads (kg year-1) for the Orakei residential catchment determined from stormwater monitoring data and using the ARC CLM with and without adjusting the reference area fractions for residential source areas

	Stormwater monitoring	CLM without adjusting the reference area fractions	CLM with adjusted area fractions
TSS	14,700	26,766	18,777
Total zinc	24.6	55.6	34.2
Total copper	3.56	3.30	3.27

4.2 Source yields

4.2.1 Roofs, roads and pervious surfaces

The yields for roof materials, roads and pervious surfaces have been derived from the most reliable data available to the authors. Nevertheless, some yields still have considerable uncertainty.

Among the more uncertain yields are those for copper and TPH in road runoff, although both of these yields are more reliable now than they were in the earlier versions of the CLM. Further improvement in the accuracy of these yields can be expected when new road runoff monitoring data becomes available.

The TSS yield for urban streams is very uncertain and will be highly variable across streams depending on the stream morphology, e.g. slope of the channel, bank structure, type of riparian vegetation, and catchment soil type. If streams are a substantial component of a catchment (this can be assessed by comparing the stream TSS loads with the total catchment TSS loads in the CLM spreadsheet), then the model user should be aware that the catchment TSS loads will have higher-than-usual uncertainty. This would be relevant to the design of an in-line pond for example.

4.2.2 Paved surfaces

As explained above, the paved surface yields were derived from the CLM calibration. Within the calibration catchments, galvanised steel roofs and vehicle tyres are the dominant sources of zinc and vehicle brake pads and discs are the dominant sources of copper. In any other catchment, so long as these are the dominant sources of zinc and copper, then the paved surface yields for these metals (and also TSS) are likely to be valid and the calculated loads will be reliable.

If it is known that the activities undertaken on the paved surfaces of a catchment could generate unusually large amounts of TSS, zinc, copper or TPH relative to the loads from the catchments roofs and roads, i.e. the paved surface yields in the CLM do not apply, then the CLM load predictions will have very large errors. This is often the case for small industrial catchments.

As industrial catchments decrease in size, the composition of the stormwater from the paved surfaces becomes increasingly influenced by the particular industrial activities in the catchment. For example, one small industrial catchment might contain a timber yard and a particle board manufacturer and another might contain a vehicle dismantler and a concrete products manufacturer. The composition of the stormwater from the paved surfaces will be substantially different and one or more of the paved surface yields used in the CLM are not likely to be valid for either catchment. The CLM should not be applied to these types of catchments.

4.3 Management option trains

The CLM restricts, to a limited extent, the selection of management options for roof runoff (eg: roof painting included only for option 1 and rain tank is not included). Selection of management options could be unrealistic, as an example a bio-media filter can be selected for option 1 and a wet pond for option 2. Although unrealistic or inefficient trains can be selected, the resulting errors in the reduced catchment loads expected to be small. The reason for this is, default LRF parameters are based on individual device performances but not on the combined performances. More details are given in Section 3.4.

In the example mentioned above, the bio-media filter will trap all TSS and particulate forms of contaminants and almost all of the dissolved forms (assuming no bypass). There will, therefore, be nothing left for the pond to trap (it could be installed for quantity control but this is not relevant to contaminant loads). If the devices were installed in the reverse sequence (the normal sequence), then the pond would trap the heavier solids and thus reduce the maintenance required for the bio-media filter. The loads passing out of the train would be almost the same in both cases.

4.4 Load reduction factors (LRF)

The most uncertain LRF in the CLM are those for catchpits (Timperley et al., 2010). There is evidence to suggest that catchpits are relatively inefficient for fine TSS and dissolved contaminants. Substantial errors in the catchpit LRF will make only minor contributions to the errors in the catchment loads.

The LRF for the second and third options in a management train (columns F and G in the CLM spreadsheet) are only approximate for two reasons.

1. For most contaminant/train combinations there are no reliable monitoring data from which to derive LRFs. The current version of the CLM uses the same LRF for a particular device irrespective of its position in a management train. The lack of data for the retention efficiencies of management option trains is universal; it is not a problem unique to the CLM.

   The type of error this lack of data causes is illustrated by two stormwater treatment ponds in series. It is commonly assumed that the retention efficiencies of the ponds for TSS will be the same. This is not so, because the particle size distribution of the stormwater TSS will decrease with passage through the first pond, so the proportion of the TSS retained by settling in the second pond will be less than that of the first pond.

2. CLM model developed in Excel spreadsheet following simple computational steps. No sophisticated computational algorithm has developed in this version to change the LRF for a device 2^{nd} or 3^{rd} in a management option train according to the LRF of the preceding device. For example, the total zinc LRF for the second option, say 30% for a constructed wetland, remains the same irrespective of the LRF of the first option, say 11% for a catchpit or 60% for a bio-media filter.

   This situation is most likely to be encountered where an unusual sequence of stormwater treatment devices has been installed in an existing catchment. In this case the model user should alter the combined LRF for the train (columns L, Q, V and AA in the CLM spreadsheet) to more accurately reflect the performance of the train.

5 Model spreadsheet

This chapter provides details of the model spreadsheet, including the method for calculating annual contaminant loads and an explanation of the spreadsheet content.

5.1 Method of calculating annual loads

The CLM calculates the annual load for each contaminant source using the following equation:

$$\text{Source Load} = \text{Source Area} \times \text{Source Yield} \times \text{Load Reduction Factor} \times \text{Area Fraction Managed} \quad \textbf{(1)}$$

Where:

Source load (g $year^{-1}$)	=	The quantity of a contaminant (g or kg) generated by a source over a one year period and available to be transported by run-off.
Source area (m^2)	=	The area of a contaminant source (m^2). For roads the road length (m) is entered into the model and the area is calculated. Stream channel area is the channel length times the effective width (defined as the wetted width of the average stream cross-section at mean flow. If the areas of some contaminant sources in large urban catchments are not known then they can, with caution, be estimated using the reference area fractions provided in Section 5.
Source yield (g m^{-2} $year^{-1}$)	=	The quantity of a contaminant generated by $1m^2$ of a source over a period of one year.
Load reduction factor	=	The fraction by which a selection of management options reduces the contaminant load. The management options include stormwater treatment and source control such as painting galvanised roofs and stabilising stream banks with timber palings. The CLM contains default load reduction factors but the model user can enter alternative values.
Area fraction managed	=	The fraction of a source area draining to a management option train. This must be a positive value less than or equal to one.

5.2 Spreadsheet cells

The CLM spreadsheet is shown in Figure 1.

There are three main data categories required to estimate the contaminant loads:

1. Compulsory input data
2. Optional input data
3. Default data

The following sections describe these different data categories and where they are contained in the worksheet.

5.3 Compulsory input data

The compulsory data types necessary to calculate contaminant loads are presented below. The data input cells are shaded in yellow in the worksheet. This is the minimum data required to calculate the contaminant load.

- total catchment area in m^2 (cell D6)
- source areas in m^2 (yellow cells in Column D) (Note: there is a check box to compare the total catchment area, which is given in cell D55)
- lengths for roads in m (yellow cells in Column C)

Appendix A (Section A.1) provides details on the typical procedure for obtaining the source areas and road lengths.

5.4 Optional input data

The following data types are optional. The data input cells are shaded in green in the spreadsheet.

- Selection of the source contaminant management options green cells in Columns E, F & G. Management options can be selected from the pull-down menu. The number of options selected for each source can be 0, 1, 2 or 3 but the train must be continuous, i.e. a second option cannot be entered without a first option. It is possible to choose impractical management options in the treatment train. It is up to the experience of the user to avoid this. (eg: 1st option as rain garden and 2nd option as wet pond)
- The area fractions (green cells in Column H). A fraction of the area of the source or site draining to the treatment train. If 100% of source area drains to the treatment train the fraction would be 1.0. If these cells are left blank when a management option has been identified, then an error message will be displayed.
- Manual load reduction factors (LRFs): This is a manual entry choice given to the user (green colour cells in Column L for TSS; Column Q for Zn; Column V for Cu and Column AA for PAH). If these cells are blank then default values will be used in the simulation. If the user finds that reduction efficiency is not appropriate for the selected treatment train, the user can change the LRF values depending on the selected stormwater management option.
- Selection of bottom of catchment contaminant management options. This part is given in a separate green block across the bottom of the spreadsheet, from row 58 to row 64. This enables the selection of management options at the bottom of the catchment. The user can select treatment devices and enter LRF parameters if the default value is unreasonable. However, user has to provide sufficient evidence (eg: field monitoring data) to support of choosing new LRF parameter.

5.5 Default data

Default parameters are given in blue shaded cells in the worksheet and these can not be altered. The user can enternate alternate LRF in the green cells. The source yield parameters are based on field data collected for diverse urban catchments within the Auckland region. Detailed discussion on parameter derivation is contained in Chapter 5 of the CLM Development Report (Timperley et al., 2010). These parameters are already calibrated and verified. More detail on the derivation of these parameters is provided in Chapter 7 and Chapter 8 in the CLM Development report. The default parameters specified in the model are:

- source yields for TSS (Column I)
- source yields for Zn (Column N)
- source yields for Cu (Column S)
- source yields for PAH (Column X)
- default load reduction factor for TSS (Column K)
- default load reduction factor for Zn (Column P)
- default load reduction factor for Cu (Column U)
- default load reduction factor for PAH (Column Z)

5.6 CLM results output

Simulated contaminant load values are shown in red colour fonts in the worksheet. Two main groups of results are generated.

A. Initial load (Uncontrolled loads) (g $year^{-1}$) <u>without</u> source control management options (Column J, Column O, Column T and Column Y)

B. Reduced load (Controlled loads) (g $year^{-1}$) <u>with</u> source control management options (Column M, Column R, Column W and Column AB)

These two types of results are combined to provide a catchment wide view of contaminant loads generated. They are displayed in the spreadsheet under two categories:

1. The first is summation rows, which are in bold fonts. The summations are:
    a. the total contaminant load (g $year^{-1}$) for urban area excluding the areas of construction sites
    b. the total contaminant load (g $year^{-1}$) for urban area including the areas of construction sites
    c. the total catchment contaminant loads (g $year^{-1}$) from all source categories, including a, b and rural sites
2. The second is a separate table at the bottom of the spreadsheet which gives the overall results of the CLM, containing the average contaminant load per year (kg $year^{-1}$) and the average contaminant yield per year (g m^{-2} $year^{-1}$).

5.7 Results interpretation

If only compulsory data are entered, the results will exclude the effects of any stormwater management options. The table at the bottom of the spreadsheet will give the average yearly contaminant load and yield for the catchment.

If both compulsory and optional data are entered, then uncontrolled and controlled (ie including stormwater management options) loads are calculated for each source area category. The contaminant load reduction efficiency can then be calculated for each source area category or for the entire catchment as below.

$$\text{Reduction efficiency} = \left(\frac{\text{Uncontrolled loads - Controlled loads}}{\text{Uncontrolled loads}} \right) \text{x } 100 \qquad (2)$$

Figure1: The ARC Contaminant Load Model spreadsheet

Contaminant Load Model

Version 2.0 March 2011

Catchment name CATCHMENT NAME

Auckland Council

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB
Catchment area (m²)				Source contaminant management train				Contaminant yields, loads, and load reduction factors																			
								Total suspended solids (TSS)					Zinc suspended particulate and dissolved (TZn)					Copper suspended particulate and dissolved (Tcu)					TPH suspended particulate and dissolved (TTPH)				
Source	Source type		Source Area (m²)	1st management option	2nd management option	3rd management option	Fraction of area draining to train	Yield (g m⁻² a⁻¹)	Initial load (g a⁻¹)	Default load reduction factor	Manual load reduction factor	Reduced load (g a⁻¹)	Yield (g m⁻² a⁻¹)	Initial load (g a⁻¹)	Default load reduction factor	Manual load reduction factor	Reduced load (g a⁻¹)	Yield (g m⁻² a⁻¹)	Initial load (g a⁻¹)	Default load reduction factor	Manual load reduction factor	Reduced load (g a⁻¹)	Yield (g m⁻² a⁻¹)	Initial load (g a⁻¹)	Default load reduction factor	Manual load reduction factor	Reduced load (g a⁻¹)
Roofs	Galvanised steel unpainted							5	0	0.00		0	2.2400	0.0	0.00		0.0	0.0003	0.0	0.00		0.0					
	Galvanised steel poorly painted							5	0	0.00		0	1.3400	0.0	0.00		0.0	0.0003	0.0	0.00		0.0					
	Galvanised steel well painted							5	0	0.00		0	0.2000	0.0	0.00		0.0	0.0003	0.0	0.00		0.0					
	Galvanised steel coated (Decramastic tiles)							12	0	0.00		0	0.2800	0.0	0.00		0.0	0.0017	0.0	0.00		0.0					
	Zinc/aluminium unpainted (Zincalume)							5	0	0.00		0	0.2000	0.0	0.00		0.0	0.0009	0.0	0.00		0.0					
	Zinc/aluminium coated (Colorsteel/Colorcote/new metal tiles)							5	0	0.00		0	0.0200	0.0	0.00		0.0	0.0016	0.0	0.00		0.0					
	Concrete							16	0	0.00		0	0.0200	0.0	0.00		0.0	0.0033	0.0	0.00		0.0					
	Copper							5	0	0.00		0	0.0000	0.0	0.00		0.0	2.1200	0.0	0.00		0.0					
	Other materials							10	0	0.00		0	0.0200	0.0	0.00		0.0	0.0020	0.0	0.00		0.0					
	Vehicles/day	*Length (m)*																									
Roads	<1000		0					21	0	0.00		0	0.0044	0.0	0.00		0.0	0.00148	0.0	0.00		0.0	0.0335	0.0	0.0		0.0
	1000-5000		0					28	0	0.00		0	0.0266	0.0	0.00		0.0	0.00887	0.0	0.00		0.0	0.2013	0.0	0.0		0.0
	5000-20000		0					53	0	0.00		0	0.1108	0.0	0.00		0.0	0.03695	0.0	0.00		0.0	0.8387	0.0	0.0		0.0
	20000-50000		0					96	0	0.00		0	0.2574	0.0	0.00		0.0	0.08579	0.0	0.00		0.0	1.9474	0.0	0.0		0.0
	50000-100000		0					158	0	0.00		0	0.4711	0.0	0.00		0.0	0.15703	0.0	0.00		0.0	3.5645	0.0	0.0		0.0
	>100000		0					234	0	0.00		0	0.7234	0.0	0.00		0.0	0.24314	0.0	0.00		0.0	5.5192	0.0	0.0		0.0
Paved Surfaces other than roads	Residential							32	0	0.00		0	0.1950	0.0	0.00		0.0	0.0360	0.0	0.00		0.0					
	Industrial							22	0	0.00		0	0.5900	0.0	0.00		0.0	0.1070	0.0	0.00		0.0					
	Commercial							32	0	0.00		0	0.0000	0.0	0.00		0.0	0.0234	0.0	0.00		0.0					
Urban Grasslands and trees	Slope < 5							45	0	0.00		0	0.0016	0.0			0.0	0.0003	0.0			0.0					
	5 < Slope <10							92	0	0.00		0	0.0032	0.0			0.0	0.0006	0.0			0.0					
	Slope >10							185	0	0.00		0	0.0065	0.0			0.0	0.0013	0.0			0.0					
Urban Stream Channel	*length x width*							6000	0	0.00		0	0.2100	0.0			0.0	0.0420	0.0			0.0					
	Urban area without construction sites		0					Totals	0	0.00		0		0.0	0.00		0.0	Totals	0.0	0.00		0.0	Totals	0.0	0.00		0.0
Construction Sites open for 12 months/year	Slope < 5							2500	0	0.00		0	0.0880	0.0			0.0	0.0180	0.0			0.0					
	5 <Slope <10							5600	0	0.00		0	0.1980	0.0			0.0	0.0390	0.0			0.0					
	Slope >10							10600	0	0.00		0	0.3710	0.0			0.0	0.0740	0.0			0.0					
	Urban area with construction sites		0					Totals	0	0.00		0	Totals	0.0	0.00		0.0	Totals	0.0	0.00		0.0	Totals	0.0	0.00		0.0
Exotic production forest	Slope <10							35	0	0.00		0	0.0012	0.0			0.0	0.0002	0.0			0.0					
	10 < Slope < 20							104	0	0.00		0	0.0036	0.0			0.0	0.0007	0.0			0.0					
	Slope >20							208	0	0.00		0	0.0073	0.0			0.0	0.0015	0.0			0.0					
Stable forest	Slope <10							14	0	0.00		0	0.0005	0.0			0.0	0.0001	0.0			0.0					
	10 < Slope < 20							42	0	0.00		0	0.0015	0.0			0.0	0.0003	0.0			0.0					
	Slope >20							83	0	0.00		0	0.0029	0.0			0.0	0.0006	0.0			0.0					
Farmed pasture	Slope <10							152	0	0.00		0	0.0053	0.0			0.0	0.0011	0.0			0.0					
	10 < Slope < 20							456	0	0.00		0	0.0160	0.0			0.0	0.0032	0.0			0.0					
	Slope >20							923	0	0.00		0	0.0320	0.0			0.0	0.0065	0.0			0.0					
Retired pasture	Slope <10							21	0	0.00		0	0.0007	0.0			0.0	0.0001	0.0			0.0					
	10 < Slope < 20							63	0	0.00		0	0.0022	0.0			0.0	0.0004	0.0			0.0					
	Slope >20							125	0	0.00		0	0.0044	0.0			0.0	0.0009	0.0			0.0					
Horticulture	*Soil type*	Volcanic						50	0	0.00		0	0.0018	0.0			0.0	0.0004	0.0			0.0					
		Sediment						100	0	0.00		0	0.0035	0.0			0.0	0.0007	0.0			0.0					
		Unknown						100	0	0.00		0	0.0035	0.0			0.0	0.0007	0.0			0.0					
	Total area of sources (m²)		0					Totals	0			0	Totals	0.0			0.0	Totals	0.0			0.0	Totals	0.0			0.0

CATCHMENT AREA EQUALS SUM OF SOURCE AREAS

Difference - 0.000

Catchment overview of contaminant loads

Bottom of the catchment contaminant management train				Load reduction factors (LRF)			Bottom of catchment out-fall Loads (kg a⁻¹)				Average yields (kg ha⁻¹ a⁻¹)			
First management option	Second management option	Third management option	Fraction of area draining to train	Contaminant	Default LRF	Manual LRF	TSS	TZn	TCu	TPH	TSS	TZn	TCu	TPH
				TSS	0.00		0.00	0.00	0.00	0.00	0.000	0.000	0.000	0.000
				TZn	0.00									
				TCu	0.00									
				TTPH	0.00									
				% Reduction with management			0.0%	0.0%	0.0%	0.0%				

6 Complex sites: A worked example

6.1 General

The most difficult site to model with the CLM is one in which different parts of the same source area drain to different management options, e.g. the runoff from different sections of one source category (roads in the 5,000-20,000 vpd category) is treated with either catchpits, raingardens or ponds. Several CLM spreadsheets are required to model this situation.

The most efficient approach in this situation is to divide the site into a number of "virtual" subcatchments all of which, in effect, drain to the site outlet. In other words,the site is modelled with several spreadsheets in parallel so that the loads can be added together. The subcatchments are virtual because their source areas do not have to be adjacent or linked in any way. All that matters is that the total area of each source summed over all the virtual catchments is the same as in the original site.

A convenient aid to this approach is to construct a flow diagram that correctly describes the stormwater drainage pathways through the site. For most situations like this, the way in which the site can be divided into virtual subcatchments and the minimum number of spreadsheets required wiil be readily apparent from such a diagram. It is emphasised that the number of spreadsheets used is immaterial; a different spreadsheet for each source category could be used. The only requirement is that the correct area for each source category is entered into a spreadsheet only once.

The following example illustrates the virtual subcatchment and parallel spreadsheet approach as well as other features of the CLM.

6.2 The hypothetical site

A hypothetical site is shown in Figure 2 (NOTE: This is a very complex example). The purpose of modelling is to estimate the loads discharged from the existing wetland at the bottom of the site.

6.3 Site source areas

Some relevant features of the site are shown in Figure 3, Figure 4 and Figure 5. The following information can be extracted from these figures:

A. The site has the following land use areas.

1. 28 ha of urban built up area consisting of (excluding roads):
    - 23 ha (10 + 7 + 6) of residential development
    - 5 ha of commercial development
2. 14 ha (2 + 8 + 4) of open space (urban grasslands) including parks, a sports field and a wetland, excluding roads
3. 8ha of stable forest (a reserve), excluding roads

4. a stream
5. an unspecified area of roads.

B. The site has the following road categories and lengths

1. <1,000 vpd 500 m (300 + 200)
2. 1,000-5,000 vpd 680 m (300 + 380)
3. 5,000 -20,000 vpd 1950 m (400 + 100 + 100 + 200 +400 + 450 + 300).

C. Other relevant information about the site includes the following.

1. Roofs drain directly into the stormwater network.
2. Residential paved surfaces drain either into road-side catchpits or into catchpits in pervious surface topographical depressions. The catchpits drain into the stormwater network.
3. Commercial paved surfaces drain into road-side raingardens and then into the stormwater network.
4. Residential pervious surfaces including construction sites drain either into road-side catchpits or into catchpits in pervious surface topographical depressions. Note that these pervious surfaces include back yards, small stream channels etc, as distinct from the 14 ha of open space.
5. Commercial pervious surfaces excluding construction sites, drain into road-side raingardens and then into the stormwater network. These pervious surfaces include unpaved yards and small stream channels.
6. The 10ha of urban open space at the lower end of the site and the 8 ha of forest drain directly to the stream.
7. The 4 ha of urban open space adjacent to the commercial area drains to ponds then to the network.
8. The runoff pathways for roads are:
   i. <1,000 vpd: 500m drains to catchpits
   ii. 1,000-5,000 vpd: 680m drains to catchpits
   iii. 5,000-20,000 vpd: 1175m drains to catchpits, 150m drains to catchpits then ponds, 425m drains to pervious surfaces and 200m drains to raingardens.
9. Stormwater network and stream
   i. The stormwater network discharges to the stream.
   ii. The stream is 1,000 m long with an average wetted cross-section of 2 m. It passes through 300 m of stable forest, 400 m of urban development and 300 m of urban grasslands before entering the existing wetland, ie, 700 m, ie, 1,400 m^2, is influenced by urban stormwater.

iii. No changes to sediment and chemical loads occur in either the network or the stream, ie no retention of solids or alteration of chemical species.

iv. All drainage from the site passes through the wetland.

Step 1

Based on the site characteristics stated above, the first step is to construct the flow diagram that describes the stormwater drainage pathways. A summary of the site information described above and flow paths for source areas are provided in Table 2.

Table 2: **Areas, lengths and drainage pathways for different parts of the hypothetical site**

Source	Area/Length	Treatment device	→	→	→	→
Residential	230,000 m^2	Pervious surfaces and catchpits	Pervious, paved and construction to catchpits		stream	wetland
Commercial	50,000 m^2	Pervious surfaces and road-side raingardens	Pervious, paved and construction to road-side raingardens		stream	wetland
Urban grasslands	100,000 m^2	--			stream	wetland
Urban grasslands	40,000 m^2	ponds	ponds		stream	wetland
Stable forest	80,000 m^2	--			stream	wetland
Road <1000vpd	500 m	catchpits	catchpits		stream	wetland
Road 1000-5000vpd	680 m	catchpits	catchpits		stream	wetland
Road 5000-20000vpd	425 m	Pervious surfaces	pervious		stream	wetland
Road 5000-20000vpd	200 m	raingardens	raingardens		stream	wetland
Road 5000-20000vpd	150 m	catchpits	catchpits	ponds	stream	wetland
Road 5000-20000vpd	1,175 m	catchpits	catchpits		stream	wetland
Stream	1,400 m^2	--				wetland

Step 2

The next step is to divide the source areas (residential and commercial) into final source categories. Note however that the type and area of roofs, paved surfaces and pervious areas have not been provided for residential and commercial developments. These areas need to be estimated from the reference area fractions provided in Table A.2 and A.3 (see Appendix A).

An example of area adjustment calculations for residential catchments based on A.2 values is given below.

Table A.2 values are:

Total roofs = 0.1924

Total paved = 0.1255

Total pervious = 0.5221

Adjusted values are:

For roofs =0.1924/(0.1924+0.1255+0.5221) = 0.2290

For paved = 0.1255/(0.1924+0.1255+0.5221) = 0.1494

For pervious = 0.5221/(0.1924+0.1255+0.5221) = 0.6215

Similarly, adjustments have been made for commercial catchment areas usingTable A.3 values (see Appendix A). Adjusted area proportions and calculated source areas for residential and commercial areas are given in Table 4.

Step 3

By this step all the source areas have been quantified and the next step is to enter these areas into the CLM spreadsheet, but one spreadsheet can accommodate only one drainage path. Therefore, in this example virtual subcatchments need to be constructed depending on the management options selected.

It is apparent that two source areas within this site, urban grasslands and roads 5,000 - 20,000 vpd, each have separate parts draining to the stream via different pathways (see Table 2). Therefore several spreadsheets are required to calculate the loads from this site. There are four different management option trains for roads 5,000 - 20,000 vpd, so a minimum of four subcatchments will be required. There are also four separate sections of urban grasslands; one each for residential and commercial landuse estimated from the reference area fractions and two areas of open space (the forest and the 10 ha park at the bottom of the site).

The following sections describe the four subcatchments (depending on the stormwater management options) considered in this assessment, as specified in the Table One categories.

Subcatchment 1 (Spreadsheet 1)

The residential source areas are entered to this spreadsheet. Some of the road areas draining to catchpits are also entered into this spreadsheet. To complete this spreadsheet, the bottom-of-site wetland is selected. The “Fractions of area draining to train” for those sources with management options must be “1”. This spreadsheet is shown Figure 5.

Subcatchment 2 (Spreadsheet 2)

The commercial source areas are entered into a second copy of the spreadsheet, together with the 425 m section of road 5,000 - 20,000 vpd draining to pervious surfaces and the bottom-of-site wetland. This spreadsheet is shown in Figure 6.

Subcatchment 3 (Spreadsheet 3)

The third spreadsheet is shown in Figure 7. This contains the 200 m section of road 5,000 - 20,000 vpd draining to raingardens, the 10 ha of open space (urban grasslands) at the bottom of the site, the main stream channel affected by urban stormwater discharges, the 8 ha of forest (stable forest) and the bottom-of-site wetland.

Subcatchment 4 (Spreadsheet 4)

The remaining source areas are entered into a fourth spreadsheet shown in Figure 8. This spreadsheet contains the 150 m section of road 5,000 - 20,000 vpd adjacent to the commercial area draining to raingardens and then to ponds, the 4 ha of urban grasslands (ie. the park) adjacent to the commercial area, and the bottom-of-site wetland.

Step 4

The final task is adding-up total loads for the site. The sum total of loads for the four subcatchments considered and the total loads for the site are given in Table 3.

Table 3

Loads (kg $year^{-1}$) calculated for the hypothetical catchment.

	TSS	Total Zn	Total Cu	TPH
Subcatchment 1	2721	11.6	0.60	6.5
Subcatchment 2	249	5.1	0.23	2.4
Subcatchment 3	3,548	0.3	0.05	0.2
Subcatchment 4	119	0.1	0.02	0.6
Total	6,637	17.1	0.90	9.7

Table 4: Division of residential and commercial areas of the hypothetical catchment into roofs, paved surfaces and pervious surfaces.

Sources	Residential reference area proportions	Residential adjusted area proportions	Residential area (m^2)	Commercial reference area proportions	Commercial adjusted area proportions	Commercial area (m^2)	Rural reference area proportions	Rural area (m^2)
Roofs galvanised steel unpainted	0.0073	0.0087	1,999	0.0372	0.0465	2,325		
Roofs galvanised steel poor paint	0.0333	0.0396	9,118	0.0730	0.0913	4,563		
Roofs galvanised steel well painted	0.0129	0.0154	3,532	0.0162	0.0203	1,013		
Roofs galvanised steel coated	0.0283	0.0337	7,749	0.0089	0.0111	556		
Roofs zinc/aluminium surfaced steel unpainted	0.0015	0.0018	411	0.0113	0.0141	706		
Roofs zinc/aluminium surfaced steel coated longrun and tiles	0.0333	0.0396	9,118	0.0489	0.0611	3,056		
Roofs concrete	0.0544	0.0646	14,868	0.0447	0.0559	2,794		
Roofs copper	0.0001	0.0001	27	0.0030	0.0038	188		
Roofs other materials	0.0214	0.0255	5,859	0.0568	0.0710	3,550		
Total roofs	0.1925	0.2290	526,811	0.3000	0.3750	18,750		
Total roads	0.1600	0.0	0	0.2000	0.0	0		
Residential paved	0.1258	0.1498	34,445	0.0	0.0	0		
Commercial paved	n/a	n/a	0	0.1600	0.2000	10,000		
Grasslands slope <5^o	0.3880	0.4619	106,238	0.2504	0.3128	15,656		
Grasslands slope 5-10^o	0.1293	0.1539	35,404	0.0835	0.1043	5,213		
Grasslands slope >10^o	0.0000	0.0	0	0.0	0.0	0		
Streams (length x width)	0.0017	0.0017	383	0.0017	0.0	6		
Construction sites Slope <5^o	0.0023	0.0027	630	0.0045	0.0060	281		
Construction sites Slope 5-10^o	0.0008	0.0010	219	0.0015	0.0020	94		
Construction sites Slope >10^o	0.0000	0.0	0	0.0	0.0	0		
Total urban pervious	0.5218	0.6212	142,874	0.3400	0.425	21,250		
Stable forest slope <10^o							0.250	20,000
Stable forest slope 10-20^o							0.500	40,000
Stable forest slope 20-30^o							0.250	20,000

Figure 2 A hypothetical complex catchment

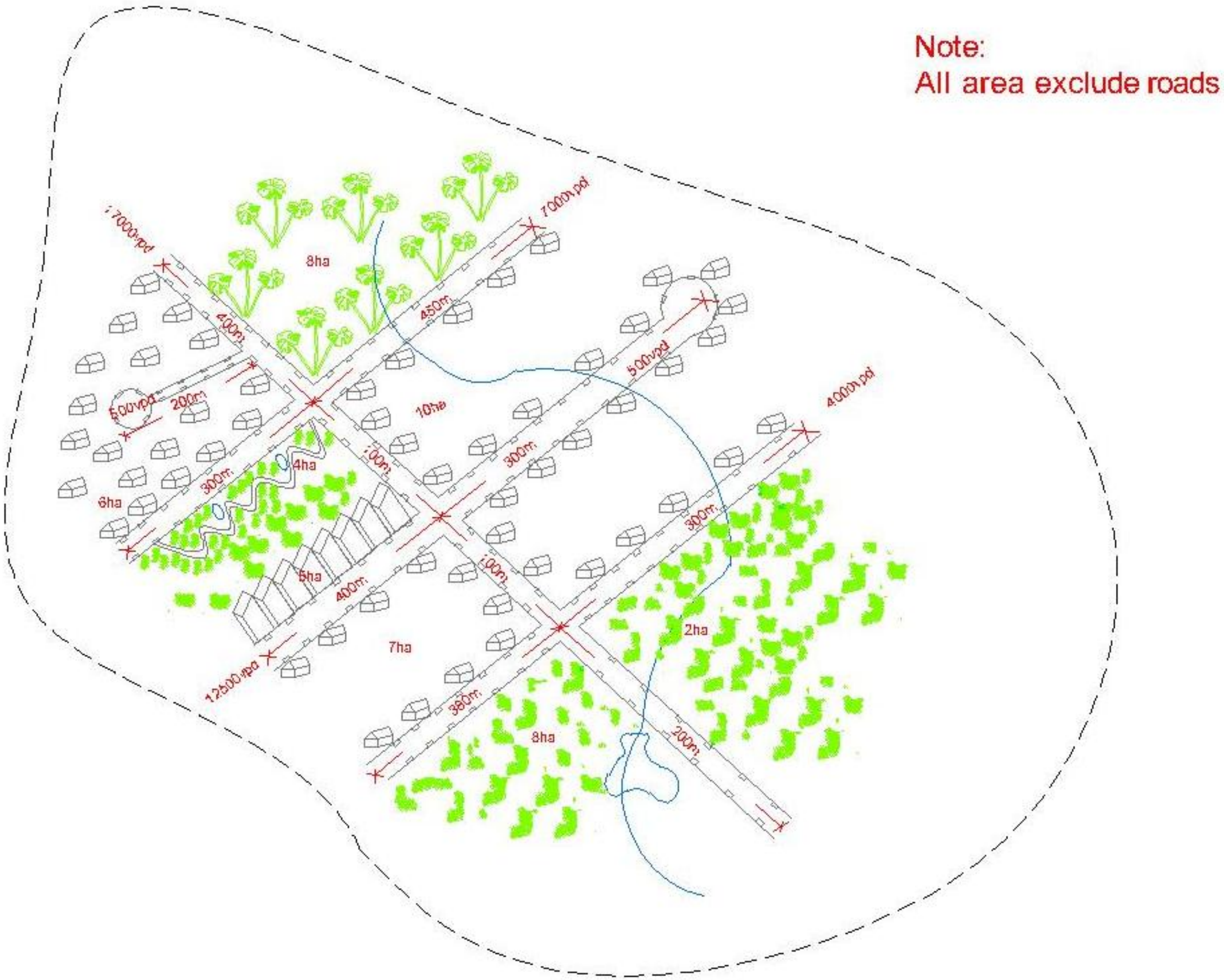
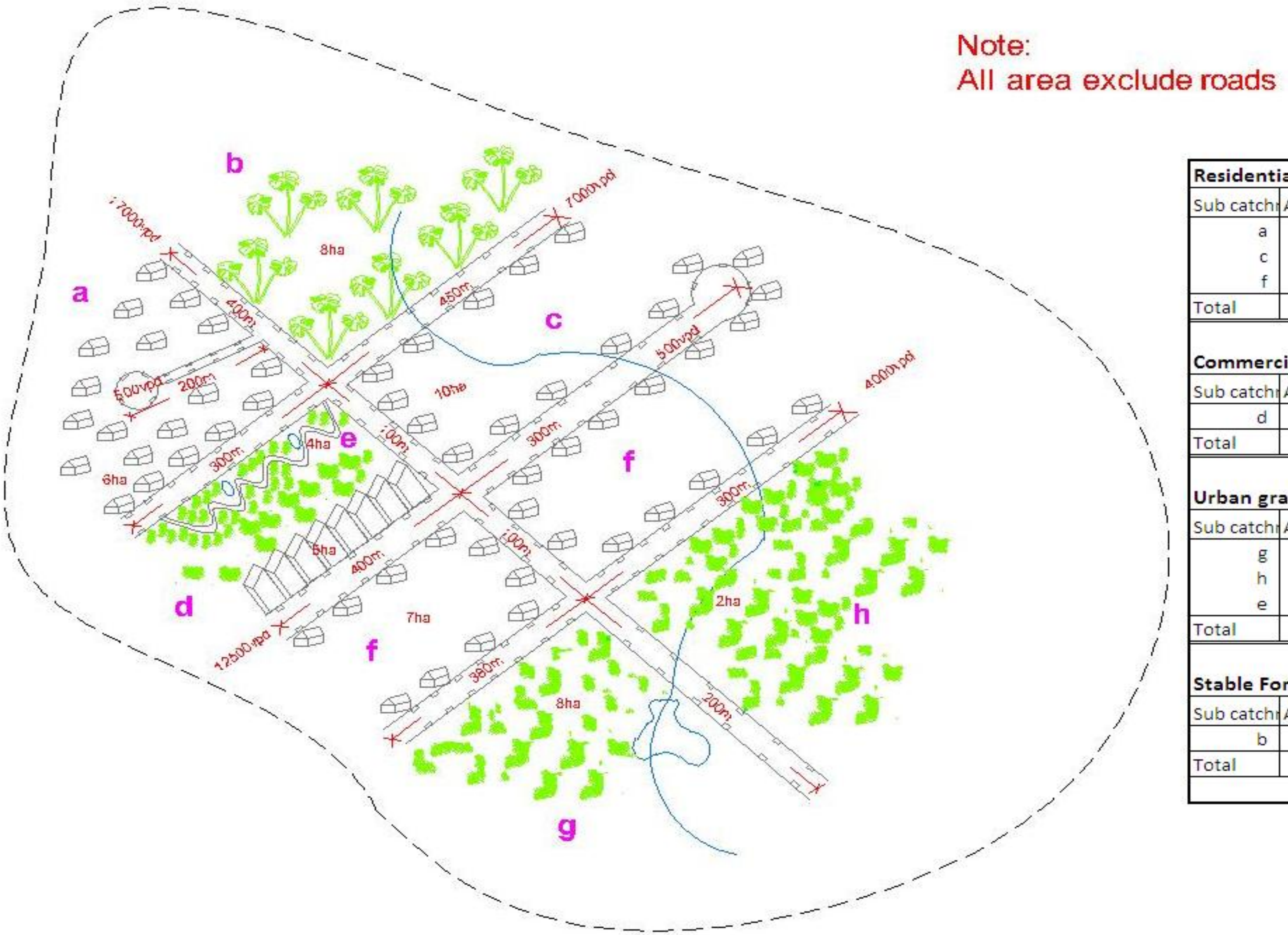
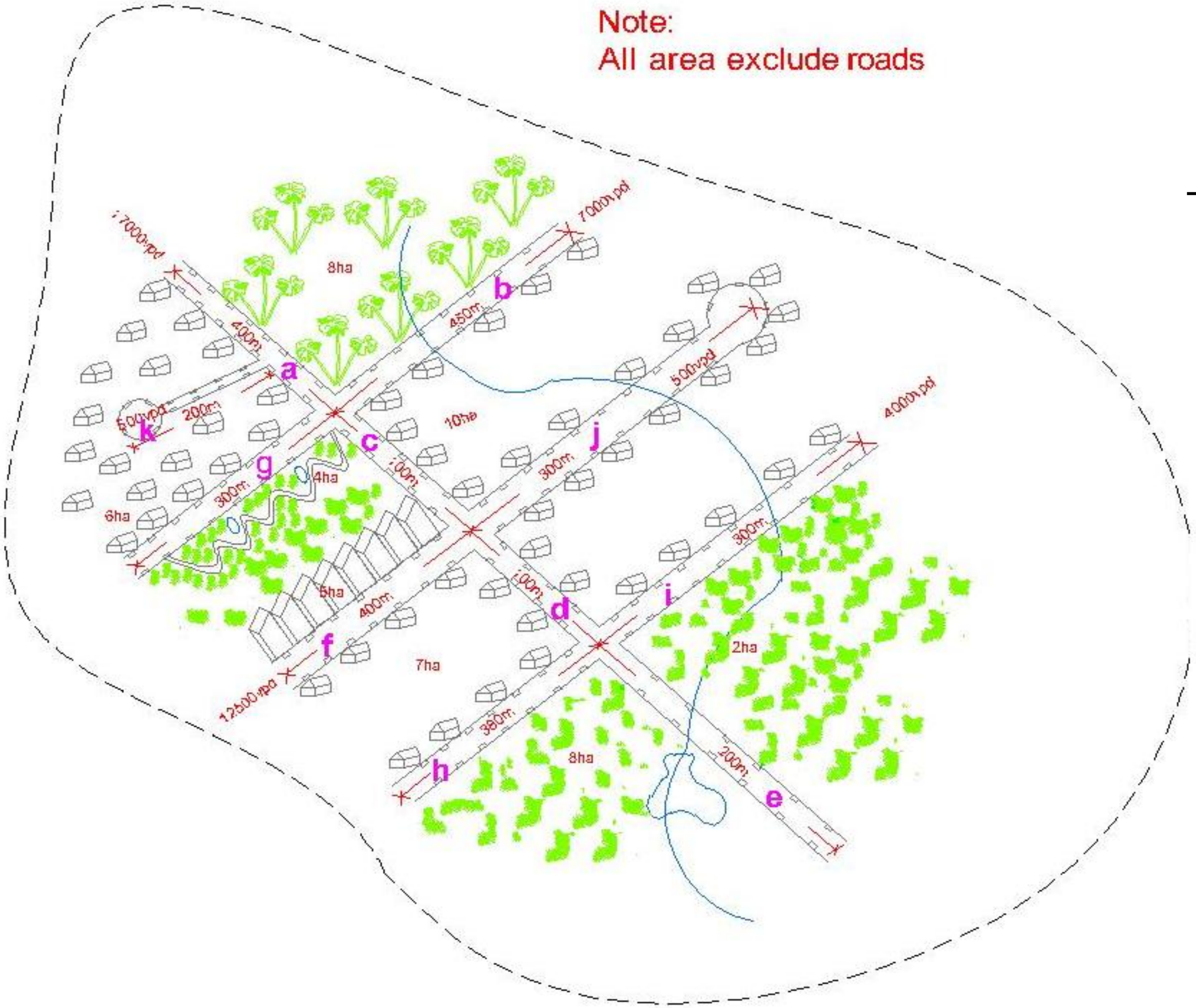


Figure 3 The complex hypothetical catchment land use areas.



Residential	
Sub catch	Area (m²)
a	6,000
c	10,000
f	7,000
Total	23,000
Commercial	
Sub catch	Area (m²)
d	5,000
Total	5,000
Urban grasslands	
Sub catch	Area (m²)
g	8,000
h	2,000
e	4,000
Total	14,000
Stable Forest	
Sub catch	Area (m²)
b	8,000
Total	8,000

Figure 4 Road areas of the hypothetical catchment



5,000 - 20, 000 vpd (discharge to catchpits)	
a	400x0.5
b	450x0.5
c	100x1.0
d	100x1.0
e	200x1.0
f	400x0.5
g	300x0.5
Total	**1175 m**
5,000 - 20,000 vpd (discharge to pervious area)	
a	400x0.5
b	450x0.5
Total	**425 m**
5,000 - 20,000 vpd (discharge to rain gardens)	
f	400x0.5
Total	**200 m**
5,000 - 20,000 vpd (discharge to catchpits then ponds)	
g	300x0.5
Total	**150 m**
1,000 - 5,000 vpd (discharge to catchpits)	
h	380x1.0
I	300x1.0
Total	**680 m**
< 1,000 vpd (discharge to catchpits)	
j	300x1.0
k	200x1.0
Total	**500 m**

Figure 5. CLM spreadsheet for subcatchment 1 of the hypothetical site loads calculation.

Contaminant Load Model

Version 2.0 March 2010

Catchment name Subcatchment 1

Auckland Council

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB
Catchment area (m^2)			270035	Source contaminant management train				Contaminant yields, loads, and load reduction factors																			
Source	Source type		Source Area (m^2)	1st management option	2nd management option	3rd management option	Fraction of area draining to train	Total suspended solids (TSS)					Zinc suspended particulate and dissolved (TZn)					Copper suspended particulate and dissolved (Tcu)					TPH suspended particulate and dissolved (TTPH)				
								Yield (g m^{-2}a^{-1})	Initial load (g a^{-1})	Default load reduction factor	Manual load reduction factor	Reduced load (g a^{-1})	Yield (g m^{-2}a^{-1})	Initial load (g a^{-1})	Default load reduction factor	Manual load reduction factor	Reduced load (g a^{-1})	Yield (g m^{-2}a^{-1})	Initial load (g a^{-1})	Default load reduction factor	Manual load reduction factor	Reduced load (g a^{-1})	Yield (g m^{-2}a^{-1})	Initial load (g a^{-1})	Default load reduction factor	Manual load reduction factor	Reduced load (g a^{-1})
Roofs	Galvanised steel unpainted		1999					5	9995	0.00		9995	2.2400	4477.8	0.00		4477.8	0.0003	0.6	0.00		0.6					
	Galvanised steel poorly painted		9118					5	45590	0.00		45590	1.3400	12218.1	0.00		12218.1	0.0003	2.7	0.00		2.7					
	Galvanised steel well painted		3532					5	17660	0.00		17660	0.2000	706.4	0.00		706.4	0.0003	1.1	0.00		1.1					
	Galvanised steel coated (Decramastic ti		7749					12	92988	0.00		92988	0.2800	2169.7	0.00		2169.7	0.0017	13.2	0.00		13.2					
	Zinc/aluminium unpainted (Zincalume)		411					5	2055	0.00		2055	0.2000	82.2	0.00		82.2	0.0009	0.4	0.00		0.4					
	Zinc/aluminium coated (Colorsteel/Colorc		9118					5	45590	0.00		45590	0.0200	182.4	0.00		182.4	0.0016	14.6	0.00		14.6					
	Concrete		14868					16	237888	0.00		237888	0.0200	297.4	0.00		297.4	0.0033	49.1	0.00		49.1					
	Copper		27					5	135	0.00		135	0.0000	0.0	0.00		0.0	2.1200	57.2	0.00		57.2					
	Other materials		5859					10	58590	0.00		58590	0.0200	117.2	0.00		117.2	0.0020	11.7	0.00		11.7					
Roads	*Vehicles/day*	*Length (m)*																									
	<1000	500	8500	Catchpits			1	21	181070	0.20		144856	0.0044	37.7	0.11		33.5	0.00148	12.6	0.15		10.7	0.0335	285.2	0.2		242.4
	1000-5000	680	11560	Catchpits			1	28	321535	0.20		257228	0.0266	307.5	0.11		273.7	0.00887	102.5	0.15		87.1	0.2013	2326.9	0.2		1977.9
	5000-20000	1175	19975	Catchpits			1	53	1049889	0.20		839911	0.1108	2214.1	0.11		1970.5	0.03695	738.0	0.15		627.3	0.8387	#####	0.2		14240.1
	20000-50000	0	0					96	0	0.00		0	0.2574	0.0	0.00		0.0	0.08579	0.0	0.00		0.0	1.9474	0.0	0.0		0.0
	50000-100000	0	0					158	0	0.00		0	0.4711	0.0	0.00		0.0	0.15703	0.0	0.00		0.0	3.5645	0.0	0.0		0.0
	>100000	0	0					234	0	0.00		0	0.7294	0.0	0.00		0.0	0.24314	0.0	0.00		0.0	5.5192	0.0	0.0		0.0
Paved Surfaces other than roads	Residential		34445	Catchpits			1	32	1102240	0.20		881792	0.1950	6716.8	0.11		5977.9	0.0360	1240.0	0.15		1054.0					
	Industrial		0					22	0	0.00		0	0.5900	0.0	0.00		0.0	0.1070	0.0	0.00		0.0					
	Commercial		0					32	0	0.00		0	0.0000	0.0	0.00		0.0	0.0294	0.0	0.00		0.0					
Urban Grasslands and trees	Slope < 5		106238	Catchpits			1	45	4780710	0.20		3824568	0.0016	167.3			133.9	0.0003	33.5			26.8					
	5 < Slope <10		35404	Catchpits			1	92	3257168	0.20		2605734	0.0032	114.0			91.2	0.0006	22.8			18.2					
	Slope >10		0					185	0	0.00		0	0.0065	0.0			0.0	0.0013	0.0			0.0					
Urban Stream Channel	*length x width*		383					6000	2298000	0.00		2298000	0.2100	80.4			80.4	0.0420	16.1			16.1					
	Urban area without construction sites		269186					Totals	13501103	0.16		11362581	Totals	29888.9	0.04		28812.3	Totals	2316.0	0.14		1990.8	Totals	#####	0.15		16460.4
Construction Site open for 12 months/year	Slope < 5		630	catchpits			1	2500	1575000	0.20		1260000	0.0880	55.1			44.1	0.0180	11.0			8.8					
	5 <Slope <10		219	catchpits			1	5600	1226400	0.20		981120	0.1980	42.9			34.3	0.0390	8.6			6.9					
	Slope >10		0					10600	0	0.00		0	0.3710	0.0			0.0	0.0740	0.0			0.0					
	Urban area with construction sites		270035					Totals	16302503	0.17		13603701	Totals	29987.0	0.04		28890.7	Totals	2335.6	0.14		2006.5	Totals	#####	0.15		16460.4
Exotic production forest	Slope <10							35	0	0.00		0	0.0012	0.0			0.0	0.0002	0.0			0.0					
	10 < Slope < 20							104	0	0.00		0	0.0036	0.0			0.0	0.0007	0.0			0.0					
	Slope >20							208	0	0.00		0	0.0073	0.0			0.0	0.0015	0.0			0.0					
Stable forest	Slope <10							14	0	0.00		0	0.0005	0.0			0.0	0.0001	0.0			0.0					
	10 < Slope < 20							42	0	0.00		0	0.0015	0.0			0.0	0.0003	0.0			0.0					
	Slope >20							83	0	0.00		0	0.0029	0.0			0.0	0.0006	0.0			0.0					
Farmed pasture	Slope <10							152	0	0.80		0	0.0053	0.0			0.0	0.0011	0.0			0.0					
	10 < Slope < 20							456	0	0.00		0	0.0160	0.0			0.0	0.0032	0.0			0.0					
	Slope >20							923	0	0.00		0	0.0320	0.0			0.0	0.0065	0.0			0.0					
Retired pasture	Slope <10							21	0	0.00		0	0.0007	0.0			0.0	0.0001	0.0			0.0					
	10 < Slope < 20							63	0	0.00		0	0.0022	0.0			0.0	0.0004	0.0			0.0					
	Slope >20							125	0	0.00		0	0.0044	0.0			0.0	0.0009	0.0			0.0					
Horticulture	*Soil type*	Volcanic						50	0	0.00		0	0.0018	0.0			0.0	0.0004	0.0			0.0					
		Sediment						100	0	0.00		0	0.0035	0.0			0.0	0.0007	0.0			0.0					
		Unknown						100	0	0.00		0	0.0035	0.0			0.0	0.0007	0.0			0.0					
	Total area of sources (m^2)		270035					Totals	16302503			13603701	Totals	29987.0			28890.7	Totals	2335.6			2006.5	Totals	#####			16460.4

CATCHMENT AREA EQUALS SUM OF SOURCE AREAS

Difference = 0.0

Catchment overview of contaminant loads

Bottom of the catchment contaminant management train				Load reduction factors (LRF)			Bottom of catchment out-fall Loads (kg a^{-1})				Average yields (kg ha^{-1} a^{-1})			
First management option	Second management option	Third management option	Fraction of area draining to train	Contaminant	Default LRF	Manual LRF	TSS	TZn	TCu	TPH	TSS	TZn	TCu	TPH
Constructed wetland			1	TSS	0.80		2720.7	11.56	0.60	6.58	100.8	0.428	0.022	0.244
				TZn	0.60									
				TCu	0.70									
				TTPH	0.60									

Figure 6 CLM spreadsheet for subcatchment 2 of the hypothetical site loads calculation

Contaminant Load Model

Version 2.0 March 2010

Catchment name Subcatchment 2

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB
Catchment area (m^2)			57226	Source contaminant management train				Contaminant yields, loads, and load reduction factors																			
								Total suspended solids (TSS)					Zinc suspended particulate and dissolved (TZn)					Copper suspended particulate and dissolved (Tcu)					TPH suspended particulate and dissolved (TTPH)				
Source	Source type		Source Area (m^2)	1st management option	2nd management option	3rd management option	Fraction of area draining to train	Yield (g $m^{-2}a^{-1}$)	Initial load (g a^{-1})	Default load reduction factor	Manual load reduction factor	Reduced load (g a^{-1})	Yield (g $m^{-2}a^{-1}$)	Initial load (g a^{-1})	Default load reduction factor	Manual load reduction factor	Reduced load (g a^{-1})	Yield (g $m^{-2}a^{-1}$)	Initial load (g a^{-1})	Default load reduction factor	Manual load reduction factor	Reduced load (g a^{-1})	Yield (g $m^{-2}a^{-1}$)	Initial load (g a^{-1})	Default load reduction factor	Manual load reduction factor	Reduced load (g a^{-1})
Roofs	Galvanised steel unpainted		2325					5	11625	0.00		11625	2.2400	5208.0	0.00		5208.0	0.0003	0.7	0.00		0.7					
	Galvanised steel poorly painted		4563					5	22815	0.00		22815	1.3400	6114.4	0.00		6114.4	0.0003	1.4	0.00		1.4					
	Galvanised steel well painted		1013					5	5065	0.00		5065	0.2000	202.6	0.00		202.6	0.0003	0.3	0.00		0.3					
	Galvanised steel coated (Decramastic ti		556					12	6672	0.00		6672	0.2800	155.7	0.00		155.7	0.0017	0.9	0.00		0.9					
	Zinc/aluminium unpainted (Zincalume)		706					5	3530	0.00		3530	0.2000	141.2	0.00		141.2	0.0009	0.6	0.00		0.6					
	Zinc/aluminium coated (Colorsteel/Color		3056					5	15280	0.00		15280	0.0200	61.1	0.00		61.1	0.0016	4.9	0.00		4.9					
	Concrete		2794					16	44704	0.00		44704	0.0200	55.9	0.00		55.9	0.0033	9.2	0.00		9.2					
	Copper		188					5	940	0.00		940	0.0000	0.0	0.00		0.0	2.1200	398.6	0.00		398.6					
	Other materials		3550					10	35500	0.00		35500	0.0200	71.0	0.00		71.0	0.0020	7.1	0.00		7.1					
Roads	*Vehicles/day*	*Length (m)*																									
	<1000		0					21	0	0.00		0	0.0044	0.0	0.00		0.0	0.00148	0.0	0.00		0.0	0.0335	0.0	0.0		0.0
	1000-5000		0					28	0	0.00		0	0.0266	0.0	0.00		0.0	0.00887	0.0	0.00		0.0	0.2013	0.0	0.0		0.0
	5000-20000	425	7225					53	379747	0.00		379747	0.1108	800.8	0.00		800.8	0.03695	266.9	0.00		266.9	0.8387	6059.6	0.0		6059.6
	20000-50000		0					96	0	0.00		0	0.2574	0.0	0.00		0.0	0.08579	0.0	0.00		0.0	1.9474	0.0	0.0		0.0
	50000-100000		0					158	0	0.00		0	0.4711	0.0	0.00		0.0	0.15703	0.0	0.00		0.0	3.5645	0.0	0.0		0.0
	>100000		0					234	0	0.00		0	0.7294	0.0	0.00		0.0	0.24314	0.0	0.00		0.0	5.5192	0.0	0.0		0.0
Paved Surfaces other than roads	Residential							32	0	0.00		0	0.1950	0.0	0.00		0.0	0.0360	0.0	0.00		0.0					
	Industrial							22	0	0.00		0	0.5900	0.0	0.00		0.0	0.1070	0.0	0.00		0.0					
	Commercial		10000	Rain garden			1	32	320000	0.75		80000	0.0000	0.0	0.70		0.0	0.0294	294.0	0.75		73.5					
Urban Grasslands and trees	Slope < 5		15656	Rain garden			1	45	704520	0.75		176130	0.0016	24.7			6.2	0.0003	4.9			1.2					
	5 < Slope <10		5213	Rain garden			1	92	479596	0.75		119899	0.0032	16.8			4.2	0.0006	3.4			0.8					
	Slope >10							185	0	0.00		0	0.0065	0.0			0.0	0.0013	0.0			0.0					
Urban Stream Channel	*length x width*		6					6000	36000	0.00		36000	0.2100	1.3			1.3	0.0420	0.3			0.3					
	Urban area without construction sites		56851					Totals	2065994	0.55		937907	Totals	12853.4	0.00		12822.4	Totals	993.2	0.23		766.5	Totals	6059.6	0.00		6059.6
Construction Site open for 12 months/year	Slope < 5		281	Wet pond			1	2500	702500	0.75		175625	0.0880	24.6			6.1	0.0180	4.9			1.2					
	5 <Slope <10		94	Wet pond			1	5600	526400	0.75		131600	0.1980	18.4			4.6	0.0390	3.7			0.9					
	Slope >10							10600	0	0.00		0	0.3710	0.0			0.0	0.0740	0.0			0.0					
	Urban area with construction sites		57226					Totals	3294894	0.62		1245132	Totals	12896.4	0.00		12833.1	Totals	1001.8	0.23		768.6	Totals	6059.6	0.00		6059.6
Exotic production forest	Slope <10							35	0	0.00		0	0.0012	0.0			0.0	0.0002	0.0			0.0					
	10 < Slope < 20							104	0	0.00		0	0.0036	0.0			0.0	0.0007	0.0			0.0					
	Slope >20							208	0	0.00		0	0.0073	0.0			0.0	0.0015	0.0			0.0					
Stable forest	Slope <10							14	0	0.00		0	0.0005	0.0			0.0	0.0001	0.0			0.0					
	10 < Slope < 20							42	0	0.00		0	0.0015	0.0			0.0	0.0003	0.0			0.0					
	Slope >20							83	0	0.00		0	0.0029	0.0			0.0	0.0006	0.0			0.0					
Farmed pasture	Slope <10							152	0	0.80		0	0.0053	0.0			0.0	0.0011	0.0			0.0					
	10 < Slope < 20							456	0	0.00		0	0.0160	0.0			0.0	0.0032	0.0			0.0					
	Slope >20							923	0	0.00		0	0.0320	0.0			0.0	0.0065	0.0			0.0					
Retired pasture	Slope <10							21	0	0.00		0	0.0007	0.0			0.0	0.0001	0.0			0.0					
	10 < Slope < 20							63	0	0.00		0	0.0022	0.0			0.0	0.0004	0.0			0.0					
	Slope >20							125	0	0.00		0	0.0044	0.0			0.0	0.0009	0.0			0.0					
Horticulture		Volcanic						50	0	0.00		0	0.0018	0.0			0.0	0.0004	0.0			0.0					
	Soil type	Sediment						100	0	0.00		0	0.0035	0.0			0.0	0.0007	0.0			0.0					
		Unknown						100	0	0.00		0	0.0035	0.0			0.0	0.0007	0.0			0.0					
	Total area of sources (m^2)		57226					Totals	3294894			1245132	Totals	12896.4			12833.1	Totals	1001.8			768.6	Totals	6059.6			6059.6

CATCHMENT AREA EQUALS SUM OF SOURCE AREAS

Difference = 0.0

Catchment overview of contaminant loads

Bottom of the catchment contaminant management train				Load reduction factors (LRF)			Bottom of catchment out-fall Loads (kg a^{-1})				Average yields (kg ha^{-1} a^{-1})			
First management option	Second management option	Third management option	Fraction of area draining to train	Contaminant	Default LRF	Manual LRF	TSS	TZn	TCu	TPH	TSS	TZn	TCu	TPH
Constructed wetland			1	TSS	0.80		249.0	5.13	0.23	2.42	43.5	0.897	0.040	0.424
				TZn	0.60									
				TCu	0.70									
				TTPH	0.60									

Figure 7 CLM spreadsheet for subcatchment 3 of the hypothetical site loads calculation.

Contaminant Load Model

Version 2.0 March 2010

Catchment name Subcatchment 3

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB
Catchment area (m²)			184800	Source contaminant management train				Contaminant yields, loads, and load reduction factors																			
								Total suspended solids (TSS)					Zinc suspended particulate and dissolved (TZn)					Copper suspended particulate and dissolved (Tcu)					TPH suspended particulate and dissolved (TTPH)				
Source	Source type		Source Area (m²)	1st management option	2nd management option	3rd management option	Fraction of area draining to train	Yield (g m⁻²a⁻¹)	Initial load (g a⁻¹)	Default load reduction factor	Manual load reduction factor	Reduced load (g a⁻¹)	Yield (g m⁻²a⁻¹)	Initial load (g a⁻¹)	Default load reduction factor	Manual load reduction factor	Reduced load (g a⁻¹)	Yield (g m⁻²a⁻¹)	Initial load (g a⁻¹)	Default load reduction factor	Manual load reduction factor	Reduced load (g a⁻¹)	Yield (g m⁻²a⁻¹)	Initial load (g a⁻¹)	Default load reduction factor	Manual load reduction factor	Reduced load (g a⁻¹)
Roofs	Galvanised steel unpainted							5	0	0.00		0	2.2400	0.0	0.00		0.0	0.0003	0.0	0.00		0.0					
	Galvanised steel poorly painted							5	0	0.00		0	1.3400	0.0	0.00		0.0	0.0003	0.0	0.00		0.0					
	Galvanised steel well painted							5	0	0.00		0	0.2000	0.0	0.00		0.0	0.0003	0.0	0.00		0.0					
	Galvanised steel coated (Decramastic tiles)							12	0	0.00		0	0.2800	0.0	0.00		0.0	0.0017	0.0	0.00		0.0					
	Zinc/aluminium unpainted (Zincalume)							5	0	0.00		0	0.2000	0.0	0.00		0.0	0.0009	0.0	0.00		0.0					
	Zinc/aluminium coated (Colorsteel/Colorcote/new metal tiles)							5	0	0.00		0	0.0200	0.0	0.00		0.0	0.0016	0.0	0.00		0.0					
	Concrete							16	0	0.00		0	0.0200	0.0	0.00		0.0	0.0033	0.0	0.00		0.0					
	Copper							5	0	0.00		0	0.0000	0.0	0.00		0.0	2.1200	0.0	0.00		0.0					
	Other materials							10	0	0.00		0	0.0200	0.0	0.00		0.0	0.0020	0.0	0.00		0.0					
Roads	*Vehicles/day*	*Length (m)*																									
	<1000		0					21	0	0.00		0	0.0044	0.0	0.00		0.0	0.00148	0.0	0.00		0.0	0.0335	0.0	0.0		0.0
	1000-5000		0					28	0	0.00		0	0.0266	0.0	0.00		0.0	0.00887	0.0	0.00		0.0	0.2013	0.0	0.0		0.0
	5000-20000	200	3400	Rain garden			1	53	178705	0.75		44676	0.1108	376.9	0.70		113.1	0.03695	125.6	0.75		31.4	0.8387	2851.6	0.8		570.3
	20000-50000		0					96	0	0.00		0	0.2574	0.0	0.00		0.0	0.08579	0.0	0.00		0.0	1.9474	0.0	0.0		0.0
	50000-100000		0					158	0	0.00		0	0.4711	0.0	0.00		0.0	0.15703	0.0	0.00		0.0	3.5645	0.0	0.0		0.0
	>100000		0					234	0	0.00		0	0.7294	0.0	0.00		0.0	0.24314	0.0	0.00		0.0	5.5192	0.0	0.0		0.0
Paved Surfaces other than roads	Residential							32	0	0.00		0	0.1950	0.0	0.00		0.0	0.0360	0.0	0.00		0.0					
	Industrial							22	0	0.00		0	0.5900	0.0	0.00		0.0	0.1070	0.0	0.00		0.0					
	Commercial							32	0	0.00		0	0.0000	0.0	0.00		0.0	0.0294	0.0	0.00		0.0					
Urban Grasslands and trees	Slope < 5		75000					45	3375000	0.00		3375000	0.0016	118.1			118.1	0.0003	23.6			23.6					
	5 < Slope <10		25000					92	2300000	0.00		2300000	0.0032	80.5			80.5	0.0006	16.1			16.1					
	Slope >10							185	0	0.00		0	0.0065	0.0			0.0	0.0013	0.0			0.0					
Urban Stream Channel	*length x width*		1400					6000	8400000	0.00		8400000	0.2100	294.0			294.0	0.0420	58.8			58.8					
	Urban area without construction sites		104800					Totals	14253705	0.01		14119676	Totals	869.5	0.30		605.7	Totals	224.1	0.42		129.9	Totals	2851.6	0.80		570.3
Construction Site open for 12 months/year	Slope < 5							2500	0	0.00		0	0.0880	0.0			0.0	0.0180	0.0			0.0					
	5 <Slope <10							5600	0	0.00		0	0.1980	0.0			0.0	0.0390	0.0			0.0					
	Slope >10							10600	0	0.00		0	0.3710	0.0			0.0	0.0740	0.0			0.0					
	Urban area with construction sites		104800					Totals	14253705	0.01		14119676	Totals	869.5	0.30		605.7	Totals	224.1	0.42		129.9	Totals	2851.6	0.80		570.3
Exotic production forest	Slope <10							35	0	0.00		0	0.0012	0.0			0.0	0.0002	0.0			0.0					
	10 < Slope < 20							104	0	0.00		0	0.0036	0.0			0.0	0.0007	0.0			0.0					
	Slope >20							208	0	0.00		0	0.0073	0.0			0.0	0.0015	0.0			0.0					
Stable forest	Slope <10		20000					14	280000	0.00		280000	0.0005	9.8			9.8	0.0001	2.0			2.0					
	10 < Slope < 20		40000					42	1680000	0.00		1680000	0.0015	58.8			58.8	0.0003	11.8			11.8					
	Slope >20		20000					83	1660000	0.00		1660000	0.0029	58.1			58.1	0.0006	11.6			11.6					
Farmed pasture	Slope <10							152	0	0.80		0	0.0053	0.0			0.0	0.0011	0.0			0.0					
	10 < Slope < 20							456	0	0.00		0	0.0160	0.0			0.0	0.0032	0.0			0.0					
	Slope >20							923	0	0.00		0	0.0320	0.0			0.0	0.0065	0.0			0.0					
Retired pasture	Slope <10							21	0	0.00		0	0.0007	0.0			0.0	0.0001	0.0			0.0					
	10 < Slope < 20							63	0	0.00		0	0.0022	0.0			0.0	0.0004	0.0			0.0					
	Slope >20							125	0	0.00		0	0.0044	0.0			0.0	0.0009	0.0			0.0					
Horticulture		Volcanic						50	0	0.00		0	0.0018	0.0			0.0	0.0004	0.0			0.0					
	Soil type	Sediment						100	0	0.00		0	0.0035	0.0			0.0	0.0007	0.0			0.0					
		Unknown						100	0	0.00		0	0.0035	0.0			0.0	0.0007	0.0			0.0					
	Total area of sources (m²)		184800					Totals	17873705			17739676	Totals	996.2			732.4	Totals	249.5			155.3	Totals	2851.6			570.3

CATCHMENT AREA EQUALS SUM OF SOURCE AREAS

Difference = 0.0

Catchment overview of contaminant loads

Bottom of the catchment contaminant management train				Load reduction factors (LRF)			Bottom of catchment out-fall Loads (kg a⁻¹)				Average yields (kg ha⁻¹ a⁻¹)			
First management option	Second management option	Third management option	Fraction of area draining to train	Contaminant	Default LRF	Manual LRF	TSS	TZn	TCu	TPH	TSS	TZn	TCu	TPH
Constructed wetland			1	TSS	0.80		3547.9	0.29	0.05	0.23	192.0	0.016	0.003	0.012
				TZn	0.60									
				TCu	0.70									
				TTPH	0.60									

Figure 8 CLM spreadsheet for subcatchment 4 of the hypothetical site loads calculation

Contaminant Load Model

Version 2.0 March 2010

Catchment name Subcatchment 4

A	B	C	D	E	F	G	H	I	J	K	L	M
Catchment area (m^2)			42550	Source contaminant management train				Contaminant yields, loads, and load reduction factors				
								Total suspended solids (TSS)				
Source	Source type		Source Area (m^2)	1st management option	2nd management option	3rd management option	Fraction of area draining to train	Yield ($g\ m^{-2}a^{-1}$)	Initial load ($g\ a^{-1}$)	Default load reduction factor	Manual load reduction factor	Reduced load ($g\ a^{-1}$)
Roofs	Galvanised steel unpainted							5	0	0.00		0
	Galvanised steel poorly painted							5	0	0.00		0
	Galvanised steel well painted							5	0	0.00		0
	Galvanised steel coated (Decramastic tiles)							12	0	0.00		0
	Zinc/aluminium unpainted (Zincalume)							5	0	0.00		0
	Zinc/aluminium coated (Colorsteel/Colorcote/new metal tiles)							5	0	0.00		0
	Concrete							16	0	0.00		0
	Copper							5	0	0.00		0
	Other materials							10	0	0.00		0
Roads	*Vehicles/day*	*Length (m)*										
	<1000		0					21	0	0.00		0
	1000-5000		0					28	0	0.00		0
	5000-20000	150	2550	Catchpits	Wet pond		1	53	134028	0.80		26806
	20000-50000		0					96	0	0.00		0
	50000-100000		0					158	0	0.00		0
	>100000		0					234	0	0.00		0
Paved Surfaces other than roads	Residential							32	0	0.00		0
	Industrial							22	0	0.00		0
	Commercial							32	0	0.00		0
Urban Grasslands and trees	Slope < 5		30000	Wet pond			1	45	1350000	0.75		337500
	5 < Slope <10		10000	Wet pond			1	92	920000	0.75		230000
	Slope >10							185	0	0.00		0
Urban Stream Channel	*length x width*							6000	0	0.00		0
	Urban area without construction sites		42550					Totals	2404028	0.75		594306
Construction Site open for 12 months/year	Slope < 5							2500	0	0.00		0
	5 <Slope <10							5600	0	0.00		0
	Slope >10							10600	0	0.00		0
	Urban area with construction sites		42550					Totals	2404028	0.75		594306
Exotic production forest	Slope <10							35	0	0.00		0
	10 < Slope < 20							104	0	0.00		0
	Slope >20							208	0	0.00		0
Stable forest	Slope <10							14	0	0.00		0
	10 < Slope < 20							42	0	0.00		0
	Slope >20							83	0	0.00		0
Farmed pasture	Slope <10							152	0	0.80		0
	10 < Slope < 20							456	0	0.00		0
	Slope >20							923	0	0.00		0
Retired pasture	Slope <10							21	0	0.00		0
	10 < Slope < 20							63	0	0.00		0
	Slope >20							125	0	0.00		0
Horticulture	*Soil type*	Volcanic						50	0	0.00		0
		Sediment						100	0	0.00		0
		Unknown						100	0	0.00		0
	Total area of sources (m^2)		42550					Totals	2404028			594306

Source type	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB
	Zinc suspended particulate and dissolved (TZn)					Copper suspended particulate and dissolved (Tcu)					TPH suspended particulate and dissolved (TTPH)				
	Yield ($g\ m^{-2}a^{-1}$)	Initial load ($g\ a^{-1}$)	Default load reduction factor	Manual load reduction factor	Reduced load ($g\ a^{-1}$)	Yield ($g\ m^{-2}a^{-1}$)	Initial load ($g\ a^{-1}$)	Default load reduction factor	Manual load reduction factor	Reduced load ($g\ a^{-1}$)	Yield ($g\ m^{-2}a^{-1}$)	Initial load ($g\ a^{-1}$)	Default load reduction factor	Manual load reduction factor	Reduced load ($g\ a^{-1}$)
Galvanised steel unpainted	2.2400	0.0	0.00		0.0	0.0003	0.0	0.00		0.0					
Galvanised steel poorly painted	1.3400	0.0	0.00		0.0	0.0003	0.0	0.00		0.0					
Galvanised steel well painted	0.2000	0.0	0.00		0.0	0.0003	0.0	0.00		0.0					
Galvanised steel coated (Decramastic tiles)	0.2800	0.0	0.00		0.0	0.0017	0.0	0.00		0.0					
Zinc/aluminium unpainted (Zincalume)	0.2000	0.0	0.00		0.0	0.0009	0.0	0.00		0.0					
Zinc/aluminium coated (Colorsteel/Colorcote/new metal tiles)	0.0200	0.0	0.00		0.0	0.0016	0.0	0.00		0.0					
Concrete	0.0200	0.0	0.00		0.0	0.0033	0.0	0.00		0.0					
Copper	0.0000	0.0	0.00		0.0	2.1200	0.0	0.00		0.0					
Other materials	0.0200	0.0	0.00		0.0	0.0020	0.0	0.00		0.0					
Vehicles/day															
<1000	0.0044	0.0	0.00		0.0	0.00148	0.0	0.00		0.0	0.0335	0.0	0.0		0.0
1000-5000	0.0266	0.0	0.00		0.0	0.00887	0.0	0.00		0.0	0.2013	0.0	0.0		0.0
5000-20000	0.1108	282.6	0.38		176.1	0.03695	94.2	0.49		48.0	0.8387	2138.7	0.3		1545.2
20000-50000	0.2574	0.0	0.00		0.0	0.08579	0.0	0.00		0.0	1.9474	0.0	0.0		0.0
50000-100000	0.4711	0.0	0.00		0.0	0.15703	0.0	0.00		0.0	3.5645	0.0	0.0		0.0
>100000	0.7294	0.0	0.00		0.0	0.24314	0.0	0.00		0.0	5.5192	0.0	0.0		0.0
Residential	0.1950	0.0	0.00		0.0	0.0360	0.0	0.00		0.0					
Industrial	0.5900	0.0	0.00		0.0	0.1070	0.0	0.00		0.0					
Commercial	0.0000	0.0	0.00		0.0	0.0294	0.0	0.00		0.0					
Slope < 5	0.0016	47.3			11.8	0.0003	9.5			2.4					
5 < Slope <10	0.0032	32.2			8.1	0.0006	6.4			1.6					
Slope >10	0.0065	0.0			0.0	0.0013	0.0			0.0					
length x width	0.2100	0.0			0.0	0.0420	0.0			0.0					
Urban area without construction sites	Totals	362.1	0.46		196.0	Totals	110.1	0.53		52.0	Totals	2138.7	0.28		1545.2
Slope < 5	0.0880	0.0			0.0	0.0180	0.0			0.0					
5 <Slope <10	0.1980	0.0			0.0	0.0390	0.0			0.0					
Slope >10	0.3710	0.0			0.0	0.0740	0.0			0.0					
Urban area with construction sites	Totals	362.1	0.46		196.0	Totals	110.1	0.53		52.0	Totals	2138.7	0.28		1545.2
Slope <10	0.0012	0.0			0.0	0.0002	0.0			0.0					
10 < Slope < 20	0.0036	0.0			0.0	0.0007	0.0			0.0					
Slope >20	0.0073	0.0			0.0	0.0015	0.0			0.0					
Slope <10	0.0005	0.0			0.0	0.0001	0.0			0.0					
10 < Slope < 20	0.0015	0.0			0.0	0.0003	0.0			0.0					
Slope >20	0.0029	0.0			0.0	0.0006	0.0			0.0					
Slope <10	0.0053	0.0			0.0	0.0011	0.0			0.0					
10 < Slope < 20	0.0160	0.0			0.0	0.0032	0.0			0.0					
Slope >20	0.0320	0.0			0.0	0.0065	0.0			0.0					
Slope <10	0.0007	0.0			0.0	0.0001	0.0			0.0					
10 < Slope < 20	0.0022	0.0			0.0	0.0004	0.0			0.0					
Slope >20	0.0044	0.0			0.0	0.0009	0.0			0.0					
Volcanic	0.0018	0.0			0.0	0.0004	0.0			0.0					
Sediment	0.0035	0.0			0.0	0.0007	0.0			0.0					
Unknown	0.0035	0.0			0.0	0.0007	0.0			0.0					
Total area of sources (m^2)	Totals	362.1			196.0	Totals	110.1			52.0	Totals	2138.7			1545.2

CATCHMENT AREA EQUALS SUM OF SOURCE AREAS
Difference = 0.0

Catchment overview of contaminant loads

Bottom of the catchment contaminant management train				Load reduction factors (LRF)			Bottom of catchment out-fall Loads ($kg\ a^{-1}$)				Average yields ($kg\ ha^{-1}\ a^{-1}$)			
First management option	Second management option	Third management option	Fraction of area draining to train	Contaminant	Default LRF	Manual LRF	TSS	TZn	TCu	TPH	TSS	TZn	TCu	TPH
Constructed wetland			1	TSS	0.80		118.9	0.08	0.02	0.62	27.9	0.018	0.004	0.145
				TZn	0.60									
				TCu	0.70									
				TTPH	0.60									

7 References

Timperley M. H., Skeen M. and Jayaratne R. (2010). Development of the ARC Contaminant Load Model. Auckland Regional Council TR 2010/004.

Timperley, M.H.; Williamson, R.B.; Mills, G.; Horne, W.; Hasan, M.Q. (2004). Sources and loads of metals in urban stormwater. ARC Technical Publication No. 318.

Green M. (2008). Central Waitemata Harbour Contaminant Study. USC-3 Model Description, Implementation and Calibration. Auckland Regional Council TR 2008/042.

Appendix A: Model inputs

A.1 Source areas

The source areas are the minimum inputs required. If only these data are entered, the model will calculate the initial loads, ie with no management options.

The following sections explain the typical procedure for obtaining the source areas. Generally this procedure involves progressively subdividing the catchment until all the areas of the individual sources are obtained, then totalling the source areas as required for model input. For example, the areas of unpainted galvanised steel roofs in residential, commercial and industrial areas are combined to produce the total area of unpainted galvanised steel roofs for input to the model. This approach ensures maximum use of known area data, because if any area data is available it will usually be for the larger land use categories, e.g. rural land or motorways (as explained below, motorway areas are entered into the CLM as roads >50,000 vpd).

If the areas of some sources are not known, as is often the case for large catchments (it should never be the case for small catchments), then the reference area fractions listed below and described in Timperley et al. (2010) can be used. These provide a basis for dividing a catchment into its constituent source areas in the absence of any catchment-specific information. The model user should understand, however, that for most catchments the values in the table will be rough approximations at best and incorrect at worst. A visual assessment of a developed catchment should be undertaken before using the model in order to avoid using inappropriate area fractions.

The model results will be meaningless if the sum of the source areas is substantially different from the total catchment area. The model checks this and either confirms that they are equal or warns that they are not.

A.1.1 Rural and urban areas

The first division of a catchment is into urban and rural areas. These areas should be readily available from GIS, zoning maps and/or aerial photographs. The CLM is for use with sites that are predominantly urban (i.e. greater than about 80%). If the rural proportion is greater than about 20% then only the urban part should be modelled with the CLM.

A.1.2 Rural land uses

Rural land use usually comprises several different GIS categories, but these can be combined to produce the areas of exotic (ie, non-indigenous) forest, native forest (ie, indigenous forest) farmed pasture, etc, required by the CLM.

A.1.3 Urban land uses

An urban area comprises one or more of residential, commercial and industrial land uses, but the areas of these land uses are not commonly available directly from GIS. Rather, the GIS urban categories are usually "urban open space" (parks, school grounds, playing fields, etc) and "urban built-up" (all urban areas other than "urban open space").

For input to the CLM there are two options for deriving the areas of residential, commercial and industrial land use from GIS areas. One option is to:

1. divide the urban built-up area into residential, commercial and industrial areas on the basis of other information e.g. district plans
2. further divide each of these areas into areas of roofs, roads, paved and pervious surfaces
3. add the source areas as required for input to the model
4. add the urban open space to the total pervious category.

The other option is to:

1. divide the built-up area as explained above (Step 1 & 2)
2. distribute the open space across the residential, commercial and industrial areas in the same area proportions as these land uses
3. divide each of the residential, commercial and industrial areas into the areas of roofs, roads, paved and pervious areas
4. total the source areas as required for input to the model.

The choice of these two options depends mainly on the information available to guide the division of the urban built-up area. (NOTE: Chapter 2 and 3 discusses the model limitations and parameter uncertainties. Also provide some guidance on how to reduce uncertainities. The model user need to be well aware on avaialable information and parameter uncertainities to determine input data to the model)

A.1.4 Roofs, roads, paved and pervious

Each of the residential, commercial and industrial areas are divided into the following four categories:

1. Roofs
2. Roads including road verges and footpaths but excluding parking areas and driveways
3. Other paved surfaces including parking areas, driveways, concrete patios, etc, but note that residential, commercial and industrial paved areas are modelled separately and have different yields
4. Pervious surfaces, i.e. all urban pervious surfaces including stable grasslands such as parks, school grounds, golf courses etc, open stream channels, blocks of trees, the

lawns and gardens of residential, commercial and industrial lots and the bare soil on construction sites.

These areas cannot generally be extracted from GIS with the exception of motorways (> 50,000 vpd). For small catchments they can be measured directly but for large catchments aerial photographs are the only practical source of these data. Digitising these areas on aerial photographs is a time-consuming and expensive process.

The alternative is to calculate these source areas using area fractions derived from other urban catchments. Evidence to support these calculations for the particular catchment should be obtained. Fortunately, as urban areas increase in size, the area fractions of roofs, roads, paved areas and pervious areas tend towards typical values. For example, the area fraction for local roads is 0.178 ± 0.057 across 30 stormwater catchments constituting 54% of the area of Auckland City (data provided by ACC/Metrowater).

A set of reference area fractions derived from data for Auckland City are listed in Table A.2 to A.4. The derivation of these fractions is described in Timperley et al., 2010.

A.1.5 Roof materials

The total roof area is divided into the areas constructed of different materials, i.e. galvanized steel (four categories), zinc-aluminium surfaced steel (two categories), concrete, copper and other materials.

As with all the source areas, the ideal approach to determining the areas of different roof materials is to identify the materials by inspection and to measure the areas from aerial photographs for all roofs within the catchment. This is feasible and has been done for several urban areas in ACC (Timperley et al, 2004), although not without some difficulties. Identifying the material usually requires a close physical inspection and this can be problematic for several reasons, including accessing building roofs and finding the expertise necessary to identify the materials.

For small catchments with a moderate number of buildings ("moderate" being determined largely by the willingness to pay for the survey, but, say, up to 50 buildings) materials and areas can be determined directly. For larger sites with many more buildings, however, there can be an understandable reluctance to commission a direct survey of roof materials and areas.

As with the total roof area, the reference area fractions for different roof materials listed in Table A.2 to A.4 can be used. Unlike total roof areas, however, the areas of different roof materials vary considerably across urban areas depending on the particular preferences of developers, architects and owners. Whole sub-divisions with a single roofing material are quite common.

For existing sites, the validity of the reference area fractions for roof materials should be checked by a "drive-by" field survey. Such a survey will quickly show if a site was developed all at one time by a developer or builder with a preference for a particular roofing material. The wide range of zinc yields discussed below for roofing materials illustrates the large errors that can result if the assumed roof materials are wrong, eg galvanised steel assumed when the reality is concrete tiles.

As sites increase in size, the mix of roof materials becomes more homogeneous. For very large sites, e.g., more than about 200 buildings, provided that the buildings in the site are of similar age to those in the areas from which the reference area fractions were derived, i.e. pre-mid 1990s, then the reference fractions should be reasonably valid. A "drive-by" survey is still advisable, however, to confirm the general applicablity of the reference values.

A.1.6 Road areas

The total road area is divided into six categories, each covering a different range of vehicles carried per day (vpd).

For modelling convenience, the total motorway area is divided into two vpd categories and the total local road area is divided into four vpd categories. If the actual vpd for the roads in a site is known then the closest vpd categories in the model should be chosen. Otherwise the reference area fractions can be used to estimate the road areas.

For most catchments road lengths are easier to obtain than road areas. The primary input for roads is, therefore, road length. The CLM calculates the road areas on the assumption that all roads comprise two or more lanes each 3.5 m wide, plus 5 m wide verges on each side, and that the relationship between the number of lanes and the vehicle capacity (vehicles/day or vpd) is <20,000 vpd two lanes, 20,000-50,000 vpd effectively three lanes, 50,000-100,000 vpd four lanes and >100,000 vpd six lanes.

If road areas are available, for example, if they have been estimated from the reference area fractions, then they can be converted to road lengths (m) outside the CLM by the following procedure. If the area includes the verge then divide the area by the following factors, 17 for roads up to 20,000 vpd, 20.5 for roads between 20,000 and 50,000 vpd, 24 for roads between 50,000 and 100,000 vpd and 31 for roads >100,000 vpd. If the road area does not include the verge divide by the following factors: seven for roads up to 20,000 vpd, 10.5 for roads between 20,000 and 50,000 vpd, 14 for roads between 50,000 and 100,000 vpd and 21 for roads greater than 100,000 vpd. If this procedure causes an imbalance in the site areas adjust the residential pervious surface until the sum of the source areas equals the total catchment area.

A.1.7 Paved areas

Paved areas are not subdivided further.

A.1.8 Pervious areas

Pervious areas are divided into stream channels with natural unstabilised banks and beds, construction sites, and urban grasslands and trees i.e. stable pervious surfaces. As for the other source areas, if these areas are not known for large sites then the reference area fractions can be used. Stream channels and construction sites generate substantial proportions of site TSS loads, so it is advisable to check the validity of the reference fractions for a particular site. For example, the actual annual TSS loads for an established high intensity residential development with neither open stream channels nor construction sites will be very much lower than the loads estimated by assuming the reference area fractions.

Urban grasslands and trees, construction sites and all the rural source areas except for horticulture, are further divided into three different slope categories. If the actual slopes are known then the appropriate areas should be entered into the closest slope categories, otherwise the areas can be divided into proportions with different slopes according to the reference values shown in Table A.1.

Table A.1. Reference fractions for slope categories

Urban pervious	$<5^o$	5^o-10^o	$>10^o$
Urban grasslands and trees	0.750	0.250	0.000
Urban construction sites	0.750	0.250	0.000
Rural	$<10^o$	10^o - 20^o	20^o - 30^o
Exotic production forest	0.250	0.500	0.250
Stable forest	0.250	0.500	0.250
Farmed pasture	0.600	0.400	0.000
Retired pasture	0.600	0.400	0.000

A.1.9 Reference area fractions

The reference area fractions derived from ACC land use data are given in Table A.2 , Table A.3 and Table A.4 . For more details about reference area fractions refer Section 4 in the CLM Development Report (Timperley et al., 2010).

A.1.10 Source areas for future years

As explained above, assessing the effects of stormwater contaminants on aquatic life requires annual catchment loads for future years. In general, estimating loads for every fifth or tenth year is sufficient to enable a suitable time trend to be fitted to the estimated loads and the annual loads to be interpolated.

The source areas, management options and the LRF can all vary over time as catchments mature and are redeveloped. In particular, developments will intensify with population growth and consequent increasing proportions of impervious surfaces, mainly building roofs, and more vehicles on the roads. Building materials will also change, eg galvanised steel will slowly disappear from building roofs.

Model users are in the best position to know what future land use changes are planned and to make the corresponding changes to source areas.

A.2 Management options

The management options available for the various source areas are shown in Table C.1 in Appendix C. Between zero and three management options in series can be chosen for each source area from pull-down menus (columns E, F and G in the spreadsheet). The model user should note the errors that can arise from the selection of inefficient option trains (Section 5.4).

A.2.1 Fraction draining to management option train

If any management options are selected then the fraction of the source draining to the option train must be entered in column H of the spreadsheet, even if the fraction is 1.0. If a fraction is not entered then the option train is ignored.

A.2.2 Load reduction factors

The CLM contains a full set of LRFs for the management options as listed in Appendix C. If the model user knows that an option train comprising between one and three options in series either is not performing, or will not perform, then the model user can enter a more realistic LRF for the train. However, please note that only the LRF for the whole train (combined reduction factors) can be changed. The LRFs for the individual options in a train of two or three options cannot be changed.

Table A.2. Proportions of a residential area that can be assumed for each source area if the area of residential development is known check alignment in each of these tables under roads

			Area Fractions
Roofs	Galvanised steel unpainted		0.0073
	Galvanised steel poorly painted		0.0333
	Galvanised steel well painted		0.0129
	Galvanised steel coated		0.0283
	Zinc/aluminium surfaced steel unpainted		0.0015
	Zinc/aluminium surfaced steel coated longrun and tiles		0.0333
	Concrete		0.0544
	Copper		0.0001
	Other materials		0.0214
	Total roofs		0.1924
Roads (vehicles/day)	<1,000		0.0896
	1,000-5,000		0.0464
	5,000-20,000		0.0192
	20,000-50,000		0.0048
	Total roads		0.1600
Paved	Residential		0.1255
Pervious	Grasslands and trees	<5	0.3880
	Slope	5-10	0.1293
		>10	0.0000
	Stream Channel length x width		.0017
	Construction Site	<5	0.0023
	Slope	5-10	0.0008
		>10	0.0000
	Total pervious		0.5221

Table A.3. Proportions of a commercial area that can be assumed for each source area if the area of commercial development is known

				Area Fractions
Roofs	Galvanised steel unpainted			0.0372
	Galvanised steel poorly painted			0.0730
	Galvanised steel well painted			0.0162
	Galvanised steel coated			0.0089
	Zinc/aluminium surfaced steel unpainted			0.0113
	Zinc/aluminium surfaced steel coated longrun and tiles			0.0489
	Concrete			0.0447
	Copper			0.0030
	Other materials			0.0568
	Total roofs			0.3000
Roads		<1,000		0.0200
		1,000-5,000		0.0600
	Vehicles/day	5,000-20,000		0.1000
		20,000-50,000		0.0200
	Total roads			0.2000
Paved	Commercial			0.1584
Pervious	Grasslands and trees		<5	0.2504
		Slope	5-10	0.0835
			>10	0.0000
	Stream Channel length x width			0.0017
	Construction Site		<5	0.0045
		Slope	5-10	0.0015
			>10	0.0000
	Total urban pervious			0.3416

Table A.4 Proportions of an industrial area that can be assumed for each source area if the area of industrial development is known

				Area Fractions
Roofs	Galvanised steel unpainted			0.1738
	Galvanised steel poorly painted			0.0083
	Galvanised steel well painted			0.0037
	Galvanised steel coated			0.0000
	Zinc/aluminium surface steel unpainted			0.0000
	Zinc/aluminium surfaced steel coated longrun and tiles			0.0075
	Concrete			0.0000
	Copper			0.0000
	Other materials			0.0066
	Total roofs			0.2000
Roads		<1,000		0.0200
		1,000-5,000		0.0600
	Vehicles/day	5,000-20,000		0.1000
		20,000-50,000		0.0200
	Total roads			0.2000
Paved	Industrial			0.2485
Pervious	Grasslands		<5	0.2625
	and trees	*Slope*	5-10	0.0875
			>10	0.0000
	Stream Channel length x width			0.0017
	Construction Site		<5	0.0000
	……………………………...	*Slope*	5-10	0.0000
			>10	0.0000
	Total urban pervious			0.3515

Appendix B: Source yields

The yields used in the CLM are given in Table B.1. These parameters cannot be changed by the model user. The origins or derivations of these yields are described in the model development report (Timperley et al, 2010). It should be noted that these yields are for the quantities of contaminants that are available to be transported in either or both suspended and dissolved forms. These yields apply <u>upstream</u> of all stormwater treatment devices, including catchpits.

Table B.1. Contaminant yields for the source areas used in the CLM. The zinc and copper yields shaded cells were derived by multiplying the TSS yield by 35 mg kg^{-1} and 7 mg kg^{-1} respectively and dividing the products by 10^{6}. (For more details refer Section 5.5 in CLM Development Report (Timperley et al., 2010)

	AREA	TSS	Total zinc	Total copper	TPH
		g m^{-2} year^{-1}	g m^{-2} year^{-1}	g m^{-2} year^{-1}	g m^{-2} year^{-1}
Roofs	galvanised steel unpainted	5	2.24	0.0003	0
	galvanised steel poor paint	5	1.34	0.0003	0
	galvanised steel well painted	5	0.20	0.0003	0
	galvanised steel coated	12	0.28	0.0017	0
	zinc/aluminium surfaced steel unpainted	5	0.20	0.0009	0
	zinc/aluminium surfaced steel coated longrun and tiles	5	0.02	0.0016	0
	concrete	16	0.02	0.0033	0
	copper	5	0.00	2.1200	0
	other materials	10	0.02	0.0020	0
Roads	<1k vpd	21	0.0044	0.0015	0.0335
	1k-5k vpd	28	0.0266	0.0089	0.2013
	5k-20k vpd	53	0.1108	0.0369	0.8387
	20K-50K	96	0.2574	0.0858	1.9474
	50k-100k vpd	158	0.4711	0.1570	3.5645
	>100K vpd	234	0.7294	0.2431	5.5192
Paved	Residential paved	32	0.1950	0.0360	0
	Industrial paved	22	0.5900	0.1070	0
	Commercial paved	32	0.0000	0.0294	0
Pervious	Urban grasslands and trees <5^{o}	45	0.0016	0.0003	0
	Slope 5-10^{o}	92	0.0032	0.0006	0
	>10^{o}	185	0.0065	0.0013	0
	Urban stream channels (length x width)	6000	0.2100	0.0420	0
	Construction sites <5^{o}	2500	0.0880	0.0180	0
	Slope 5-10^{o}	5600	0.1960	0.0390	0
	>10^{o}	106000	0.3710	0.0740	0
Rural	Exotic production forest <10^{o}	35	0.0012	0.0002	0
	Slope 10-20^{o}	104	0.0036	0.0007	0
	20-	208	0.0073	0.0015	0
	Stable forest <10^{o}	14	0.0005	0.0001	0

		Slope	10-20°	42	0.0015	0.0003	0
			20-	83	0.0029	0.0006	0
	Farmed pasture		<10°	152	0.0053	0.0011	0
		Slope	10-20°	456	0.0160	0.0032	0
			20-	923	0.0320	0.0065	0
	Retired pasture		<10°	21	0.0007	0.0001	0
		Slope	10-20°	63	0.0022	0.0004	0
			20-	125	0.0044	0.0009	0
	Horticulture	Volcanic soil		50	0.0018	0.0004	0
		Sedimentary soil		100	0.0035	0.0007	0
		Unknown soil		100	0.0035	0.0007	0

Appendix C: Load reduction factors

The term "load reduction factor" (LRF) refers to the proportion by which contaminant loads can be reduced by management options that include source control measures such as roof painting and stream bank stabilisation, as well as stormwater treatment. For stormwater treatment devices the LRFs are the treatment or contaminant retention efficiencies.

The CLM includes a full set of default LRF for all management options as shown in Table C.1. These LRFs were chosen to be the highest load reductions likely to be achieved by a correctly designed, implemented (or installed for an engineered device), and maintained management option. The LRF for an option train can be changed by the model user as explained in Section 5.4.

Table C.1. Load reduction factors used for the CLM management options irrespective of the option position in the management train

Roofs

	Load reduction factor			
Treatment Option	TSS	Zn	Cu	TPH
Biomediafiltration	0.75	0.60	0.70	0.00
Constructed wetland	0.50	0.25	0.30	0.00
Dry pond	0.10	0.05	0.05	0.00
Painting	0.00	0.90	0.90	0.00
Rain garden	0.70	0.60	0.70	0.00
Sand-filter	0.50	0.10	0.15	0.00
Storm-filter	0.50	0.15	0.20	0.00
Swale	0.30	0.15	0.20	0.00
Vegetative filter strips	0.20	0.10	0.20	0.00
Wet extended pond	0.20	0.10	0.10	0.00
Wet pond	0.10	0.05	0.05	0.00
Wet pond with flocculation	0.80	0.40	0.60	0.00

Roads and other paved surfaces

	Load reduction factor			
Treatment Option	TSS	Zn	Cu	TPH
Biomediafiltration	0.75	0.60	0.70	0.70
Catchpit filter	0.40	0.20	0.25	0.30
Catchpits	0.20	0.11	0.15	0.15
Constructed wetland	0.80	0.60	0.70	0.60
Dry pond	0.60	0.20	0.30	0.10
Porous paving	0.50	0.30	0.40	0.50
Rain garden	0.75	0.70	0.75	0.80
Sand-filter	0.75	0.30	0.40	0.70
Storm-filter	0.75	0.40	0.65	0.75
Swale	0.75	0.40	0.50	0.40
Vegetative filter strips	0.30	0.10	0.20	0.30
Wet extended pond	0.80	0.40	0.50	0.20
Wet pond	0.75	0.30	0.40	0.15
Wet pond with flocculation	0.80	0.50	0.60	0.50

Urban grasslands and trees, construction sites and bottom-of-site

	Load reduction factor			
Treatment Option	TSS	Zn	Cu	TPH
Biomediafiltration	0.75			
Catchpit filter	0.40			
Catchpits	0.20			
Constructed wetland	0.80			
Dry pond	0.60			
Porous paving	0.50			
Rain garden	0.75			
Sand-filter	0.75			
Storm-filter	0.75			
Swale	0.75			
Vegetative filter strips	0.30			
Wet extended pond	0.80			
Wet pond	0.75			
Wet pond with flocculation	0.80			

Stream Channels

	Load reduction factor			
Treatment Option	TSS	Zn	Cu	TPH
Concrete Channel	1.00			
Enclose (pipe)	1.00			
Rock, timber bank protection	0.75			