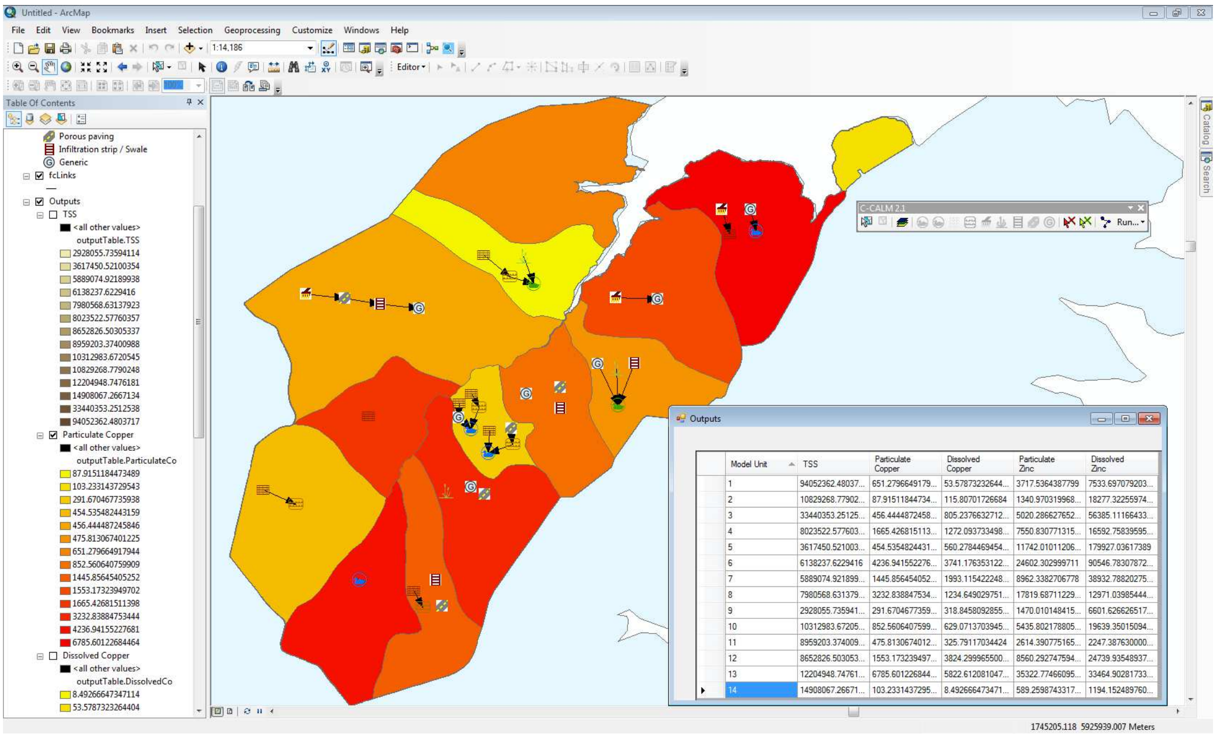
C-CALM 2.0 User Manual

Catchment Contaminant Annual Load Model

August 2014



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Front page image: C-CALM output for particulate copper simulated for hypothetical land uses and stormwater treatment options used in this manual.

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Executive summary

The Catchment Contaminant Annual Loads Model (C-CALM) was developed by NIWA under sub-contract to Landcare Research. C-CALM is provided to users free of charge for non-commercial use and is intended to aid in the planning of urban stormwater treatment at the stormwater unit / sub-catchment scale. It has been developed to be easy to use with minimal set-up and run times and modest data requirements. C-CALM consists of a GIS modelling interface linked to a contaminant loads model and a query library of performance rules for stormwater treatment options. The coupling of the loads model to a GIS interface means that C-CALM can be described as a spatial decision support system (SDSS), that is, it is an interactive model designed to support land use decisions, solve semi-structured spatial problems and provide an effective tool to aid geo-visualisation and communication between stakeholders.

C-CALM estimates annual contaminant loads from diffuse sources for total suspended solids (TSS, five particle grain size distributions can be simulated) and particulate and dissolved zinc and copper. Treatment options that can be simulated are:

- wet detention ponds;
- wetlands;
- filters;
- raingardens (i.e., bio-retention);
- swales and infiltration surfaces (i.e., vegetated bio-filters);
- catch-pits (with and without inserts);
- street sweeping;
- porous paving; and
- generic treatment (user specified removal efficiencies)

The performance rules vary according to the type, design of the treatment option and catchment characteristics, including regional location. The contaminant load calculations are based on the Auckland Council spreadsheet Catchment Loads Model (CLM, Auckland Regional Council, 2010; Timperley et al., 2010). The points of difference between CLM and C-CALM are that C-CALM: (1) operates within a GIS platform; (2) allows runoff from a specific source to be split between different treatment options; (3) has a query library to allow variable treatment efficiencies for the treatment options listed above; (4) allows complex treatment scenarios to be set-up which have no restrictions on train configuration or the number of treatment options; and (5) partitions metals into particulate and dissolved forms rather than total metals.

C-CALM is supplied as a tool-bar for ArcMap which is split into sections for the following: sub-catchment selection; data importation; insertion of treatment options; editing treatment options; model run and display. Users are asked to supply the spatial data needed to run the model; the minimum data required are sub-catchment boundaries and a breakdown of land covers found in each sub-catchment (entered using an Excel spreadsheet template). Users

are then able to add treatment options to each sub-catchment; each treatment option is customised for catchment and device characteristics, and the contaminant sources. Treatment trains can be simulated by C-CALM with successive removals of contaminants, however, C-CALM does not simulate surface flows or device hydraulics. Running the model generates a set of display map layers and a summary table which gives the annual load for each contaminant listed by sub-catchment.

The use of the query library means that C-CALM provides flexibility in assessing the effectiveness of different stormwater treatment options. Where possible, the performance rules held in the query library have been derived from multiple runs of continuous simulation models of water treatment. For treatment options where modelling was not possible due to lack of data for model development, the performance rules were derived from evaluation of literature values of removal efficiencies. For the modelled rules, the performance varies by region (in response to climate, i.e., rainfall and evapotranspiration), catchment type, device design (e.g., dimensions and outlet characteristics) and particle size distribution. The development of the performance rules is detailed in Semadeni-Davies (2008 a and b) and Harper *et al*. (2008), and sensitivity analyses of the modelled results are supplied in Semadeni-Davies and Harper (2008).

This manual is arranged into two parts: first, an overview of the C-CALM project and modelling context (Sections 1 and 2), followed by instructions for using C-CALM including examples of different treatment set-ups (Sections 3 to 6). In addition, there are five appendices. Software terms and conditions are appended in Appendix A. Appendix B gives the model set-up for the hypothetical example used to demonstrate model usage. Appendix C overviews the treatment options and their performance ratings. Appendix D gives guidance on how to assign hydraulic efficiency ratings for wet detention ponds. Finally, a bibliography of documents relating to C-CALM development and applications is provided in Appendix E.

1 Model Background

Many cities in New Zealand are located on natural streams, rivers, harbours or estuaries and the health of these aquatic environments is closely linked to the quality of contaminants transported in urban stormwater (e.g., Kelly, 2010). Sediments are a particular concern, not only as high yields can potentially damage benthic invertebrate communities by smothering or changing substrate grain size (Norkko, 1999), but because contaminants from urban land uses tend to bind to sediments (Bibby and Webster-Brown, 2005; Bibby and Webster-Brown, 2006) leading to further habitat degradation. Dissolved forms of stormwater contaminants can also cause adverse effects, especially in small urban streams where elevated concentrations can be toxic to fish and stream invertebrates (Paul and Meyer, 2001). In order to safeguard these receiving environments, there has been a move by regional and local governments to require treatment of stormwater. Installation of sustainable urban drainage systems (SUDS) as an integral part of Water Sensitive Urban Design (WSUD, see definition in Hoyer et al., 2011; Fletcher et al., 2014) has also been encouraged (e.g., Auckland Council, 2013). However, to date WSUD and SUDS have been largely restricted to green-field developments in the main centres and most urban drainage systems continue to largely consist of a reticulated network, with or without proprietary devices, to convey stormwater from source to receiving water.

One of the reasons behind the slow uptake of WSUD and SUDS in is the difficultly of demonstrating the impacts of different urban forms and stormwater management options to stakeholders (Brown et al., 2005; Brown and Clarke, 2007; Puddephatt and Heslop, 2007). Moreover, while there has been some work to establish links between urbanisation, stormwater management and environmental health including both catchment monitoring and harbour sediment sampling, the long-term impacts of continued urbanisation are difficult to assess. At the planning level, three key questions arise with respect to urbanization and land use change:

- What are the rates of long-term contaminant delivery to receiving environments?
- How will continued urban development affect these rates? and
- How can different stormwater management options reduce the impact of urbanisation?

The need for a tool which could be used to answer these questions was established in 2005 by Landcare Research Ltd as part of the Low Impact Urban Design and Development (LIUDD)[1] research programme funded by the Foundation for Research, Science and Technology (FRST)[2]. NIWA first developed the Catchment Contaminant Annual Loads Model (C-CALM) under sub-contract to Landcare Research as part of this programme. Life-cycle costing of treatment options was also evaluated as part of the LIUDD programme resulting in the development of the CostNZ model (Ira, 2007).

[1] The term LIUDD was coined by Landcare Research and is broadly equivalent to the more internationally well-known term Water Sensitive Urban Design or WSUD, see Fletcher et al. (2014)
[2] FRST has since been replaced by the Ministry of Business, Innovation and Employment

The first step in the development of C-CALM was to determine user requirements. A workshop for stormwater managers held by NIWA in June 2006 set the scope for a nationally available modelling tool for planning applications that could be provided to developers and local government. At this meeting, there was a consensus that urban drainage models, such as InfoWorks, Mike Urban and SWMM, which include water quality and treatment routines are generally too demanding of data requirements, set-up and run times and user expertise for broad planning purposes. While the Australian MUSIC model (Cooperative Research Centre for Catchment Hydrology, 2005) was considered an option for planning at the workshop, MUSIC does not simulate metals which are key urban contaminants affecting New Zealand's freshwater and coastal receiving environments. It was specified that the model should be simple and intuitive to use, with minimal data and handling requirements, so that a range of alternatives for land use zoning and intensity with different stormwater management strategies could be assessed. Moreover, the model should be built within a GIS framework as a spatial decision support system (SDSS). It was noted that most councils have GIS databases for storing spatial data including impervious surfaces, catchments / stormwater management units, land use zones, building footprints, storm- and wastewater pipe networks, location and type of stormwater treatment options, roads and streams. An SDSS incorporating this information would enable areas contributing high contaminant loads to be easily identified. Moreover, geo-visualisation would also enable local water managers to better communicate the impacts of urbanisation and water treatment to other stakeholders.

Since C-CALM's initial development, the importance of tools which allow geo-visualisation to facilitate communication between decision makers and other stakeholders has been discussed in the context of reforms to freshwater management in New Zealand (Ministry for the Environment, 2013a; 2013b), as part of the implementation strategy for the National Policy Statement for Freshwater Management (Ministry for the Environment, 2011; 2014). Such tools should have the ability to simulate the range of contaminants to be managed at the catchment scale and to take into account the range of land uses and mitigations present in a catchment (Land and Water Forum, 2012). The ability of C-CALM to simulate different treatment options and land use scenarios, and to present results in both map and tabular format mean that the model is well-suited for use in setting and maintaining contaminant load limits to achieve water quality objectives in urban streams. Further model development in this regard is ongoing. Freshwater management reform in the context of urban stormwater management has been discussed in more detail by Semadeni-Davies et al. (2014).

This manual is arranged into two parts: the modelling context is discussed in Section 2, followed by instructions for using C-CALM including examples of different treatment set-ups (Sections 3 to 6). In addition, there are five appendices. Software terms and conditions are appended in Appendix A. Appendix B gives the model set-up for the hypothetical example used to demonstrate model usage. Appendix C overviews the treatment options and their performance ratings. Appendix D gives guidance on how to assign hydraulic efficiency ratings for wet detention ponds. Finally, a bibliography of documents relating to C-CALM development and applications is provided in Appendix E.

2 Modelling Context

Fundamental to C-CALM is the difference between models for urban stormwater planning, and those for design and operation. These tasks are related and often include similar routines, however, the spatial and temporal resolution and the degree of model complexity can differ significantly. The C-CALM SDSS has been developed as a planning tool at the stormwater management unit (SMU, or sub-catchment) scale, and consists of a GIS modelling interface linked to a contaminant loads model and a query library of performance rules for stormwater treatment options. Where possible the performance rules have been derived from multiple runs of continuous simulation models of water treatment. For those treatment options which could not be modelled, the performance rules have been derived from evaluation of literature values of removal efficiencies. For the modelled rules, the performance varies by region due to climate (i.e., rainfall and evapotranspiration). C-CALM provides annual contaminant loads for each SMU from diffuse sources for total suspended solids (TSS, five particle grain size distributions can be simulated) and particulate and dissolved zinc and copper. The minimum data required are land cover type and SMU boundaries.

Treatment options that can be simulated are:

- wet detention ponds;
- wetlands;
- filters
- raingardens (i.e., bio-retention);
- swales and infiltration surfaces (i.e., vegetated bio-filters);
- catchpits (with and without inserts);
- street sweeping; and
- porous paving.
- generic treatment (user specified removal efficiencies)

These options were chosen on the basis of a telephone survey (Semadeni-Davies, 2008a) and represent the most commonly available treatment options used in New Zealand.

2.1 Load calculation

C-CALM relates annual contaminant loads to catchment land use, represented by land surface covers, according to the relationships found by Timperley et al. (2005). These relationships also form the basis of the spreadsheet model Contaminants Loads Model (CLM; Auckland Regional Council, 2010; Timperley, 2007; 2010) developed by Auckland Council[3] which has become a standard planning tool in the Auckland region. The results of both models can be used to indicate the long-term (chronic) impacts of urbanization on

[3] formerly Auckland Regional Council

receiving waters. These impacts reflect the average conditions under the assumption that most pollutant loads are transported by frequent low intensity events.

CLM and C-CALM relate the annual contaminant load from a particular source to both the surface coverage of that source and the removal efficiency of treatment options to which it is linked. The load calculation is:

Annual source load = area surface cover x annual yield x treatment reduction factor

The surface covers and their respective yields used in both CLM and C-CALM are given in Table 2-1. Land cover classes (i.e., sources) include roofing material, roads, other impervious surfaces (e.g., paving), construction sites and vegetated surfaces. The total contaminant load for a SMU is the sum of the loads from the different cover classes. The annual time-step means that catchment hydrology and contaminant transport processes simplify the models and reduce data requirements. Conceptually, while the load delivered by a specific event depends on the accumulation rate, the length of the antecedent dry period and the rainfall intensity, over the course of a year, the total wash-off from a surface is independent of rainfall dynamics. That is, accumulation and wash-off are assumed to be in equilibrium over the long term.

Where C-CALM and CLM differ is in the treatment reduction factors. For CLM, once the contaminant loads are calculated for each source type separately, there are up to three water treatment options allowed. The treatment reduction factor for each option is pre-defined under the assumption that the device has been designed according to the criteria laid out in TP10 (Auckland Regional Council, 2003), and is functioning as intended. In contrast, the C-CALM treatment reduction factors are obtained by querying the performance rule library, which contains values that are customised for each option and catchment characteristics. This allows for, amongst other things, variable removal efficiencies within each treatment option, and variable sediment and particulate removal depending on the type of treatment and the sediment particle size distribution (PSD).

Other points of difference between CLM and C-CALM are that C-CALM:

- operates within a GIS platform allowing more than one catchment to be simulated at a time and graphical map displays as well as tabulated results (i.e, C-CALM is a semi-distributed model);
- allows runoff from a specific source to be split between different treatment options;
- allows complex treatment scenarios to be set-up which have no restrictions on train configuration or the number of treatment options;
- has a variable PSD; and
- partitions metals into particulate and dissolved forms rather than total metals.

Table 2-1: Surface covers and respective annual contaminant yields used in load calculations by both CLM and C-CALM. (Auckland Regional Council, 2010; Timperley et al., 2010)

SOURCE	SOURCE TYPE		Yield (g/m^2/year)		
			TSS	Zn	Cu
Roofs	Galvanised steel unpainted		5	2.2400	0.0003
	Galvanised steel poorly painted		5	1.3400	0.0003
	Galvanised steel well painted		5	0.2000	0.0003
	Galvanised steel coated (Decramastic tiles)		12	0.2800	0.0017
	Zinc/aluminium unpainted (Zincalume)		5	0.2000	0.0009
	Zinc/aluminium coated (Colorsteel/Colorcote/new metal tiles)		5	0.0200	0.0016
	Concrete		16	0.0200	0.0033
	Copper		5	0.0000	2.1200
	Other materials		10	0.0200	0.0020
Roads Annual Average Daily Traffic expressed as vehicles per day (v.p.d.) Assumed road width given in parentheses	<1000	(17 m)	21	0.0440	0.0015
	1000-5000	(17 m)	28	0.0266	0.0089
	5000-20000	(17 m)	53	0.1108	0.0369
	20000-50000	(21 m)	96	0.2574	0.0858
	50000-100000	(24 m)	158	0.4711	0.1570
	>100000	(31 m)	234	0.7294	0.2431
Paved Surfaces	Residential		32	0.1950	0.0360
	Industrial		22	0.5900	0.1070
	Commercial		32	0.1600	0.0294
Urban Grasslands and trees	Slope <10°		45	0.0016	0.0003
	Slope 10-20°		92	0.0032	0.0006
	Slope >20°		185	0.0065	0.0013
Urban Stream Channel			6000	0.2100	0.0420
Construction Site	Slope <10°		2500	0.0880	0.0180
	Slope 10-20°		5600	0.1960	0.0390
	Slope >20°		10600	0.3710	0.0740
Exotic production forest	Slope <10°		35	0.0012	0.0002
	Slope 10-20°		104	0.0036	0.0007
	Slope >20°		208	0.0073	0.0015
Stable forest	Slope <10°		14	0.0005	0.0001
	Slope 10-20°		42	0.0015	0.0003
	Slope >20°		83	0.0029	0.0006

SOURCE	SOURCE TYPE	Yield (g/m²/year)		
		TSS	Zn	Cu
Farmed pasture	Slope <10°	152	0.0053	0.0011
	Slope 10-20°	456	0.0160	0.0032
	Slope >20°	923	0.0320	0.0065
Retired pasture	Slope <10°	21	0.0007	0.0001
	Slope 10-20°	63	0.0022	0.0004
	Slope >20°	125	0.0044	0.0009
Horticulture	Volcanic soil	50	0.0018	0.0004
	Sedimentary soil	100	0.0035	0.0007
	Unknown soil	100	0.0035	0.0007
	Permeable zinc yield = TSS yield x $35x10^{-6}$			
	Permeable copper yield = TSS yield x $7x10^{-6}$			

2.2 C-CALM as a SDSS for freshwater management

C-CALM embeds a modified version of the CLM spreadsheet model within a GIS platform. This offers a new suite of applications by allowing spatial distribution of model inputs and outputs and a tool for geo-visualization, meaning that C-CALM can be described as a SDSS. An SDSS is an interactive model designed to support a user or group of users to make land use decisions and to solve semi-structured spatial problems. An SDSS also provides a tool for more effective communication between stakeholders (Armstrong et al., 1986; Densham, 1991). The key components of an SDSS are:

- a database management system to input, store and analyse spatial data;
- the ability to represent spatial relationships;
- a library of sub-routines that can be used to query the spatial data to forecast the possible outcome of decisions; and
- the ability to display and report results in a variety of forms.

The interaction between the user and the component parts of the C-CALM SDSS to test water treatment alternatives is shown in Figure 2-1. The model libraries (Figure 2-2) are contained in a geospatial database and include model variables such as treatment types and the source yields in Table 2-1, and the performance rules for simulating water treatment as discussed in Section 2.5.

Central to the functionality of an SDSS is the provision of tools for geo-visualisation of inputs and outputs. Geo-visualisation (MacEachren and Kraak, 2001; Dykes et al., 2005) for decision making requires, amongst other things, the ability to:

- overview (pan) spatial data to identify change and/or areas of interest;
- zoom into the detail of an area of interest or out to the wider spatial pattern;
- filter redundant information;

- interact with or query the spatial data to change the information displayed; and
- extract and report on spatial data and spatial relationships.

Hüffmeyer et al. (2009) successfully simulated zinc loads from urban diffuse sources (along with agricultural sources and point sources such as combined sewer overflow), albeit without water treatment, using a very similar yields-based approach. Their model was run with an annual time-step, and coupled to a river flow model assuming steady state conditions, for the Ruhr river basin. This work demonstrates how powerful a simple contaminants load model can be for conveying information when coupled to a GIS platform for geo-visualisation.

ESRI GIS software (ArcMap 10.1)[4] was chosen as the platform for C-CALM rather than creating a standalone product as ArcMap is widely used by regional and local government in New Zealand. ArcMap has powerful tools for spatial data storage, management, analysis and display. The C-CALM interface is supplied as an add-in toolbar and includes tools for creating land use and treatment scenarios and toggling between output displays. Users are able to employ standard GIS functions included in ArcMap to complement the C-CALM options for analysis and display. Other spatial data can be imported for display (e.g., stream and road networks) without affecting the model. Furthermore, C-CALM result tables can be exported into other software packages for reporting or post analysis.

More information on the use of SDSSs, including C-CALM, for stormwater management can be found in Semadeni-Davies (2011).

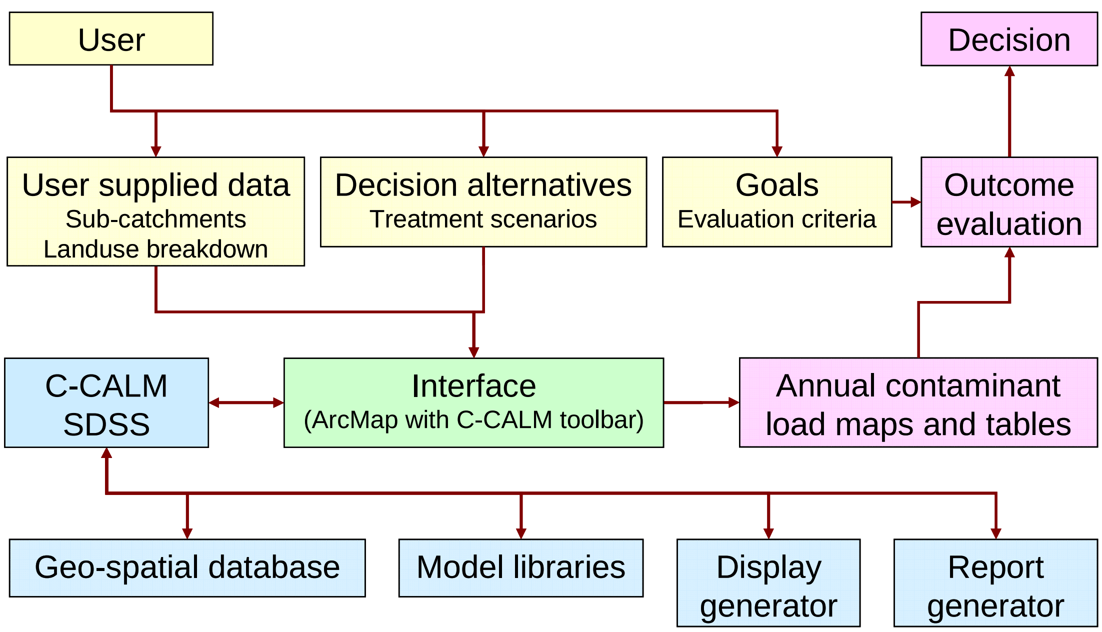


Figure 2-1: User interaction (yellow) with the C-CALM SDSS (blue) via the user interface (green) to give outcome alternatives leading to a decision (pink).

[4] http://www.esri.com/software/arcgis (date of last access 29 May 2014)

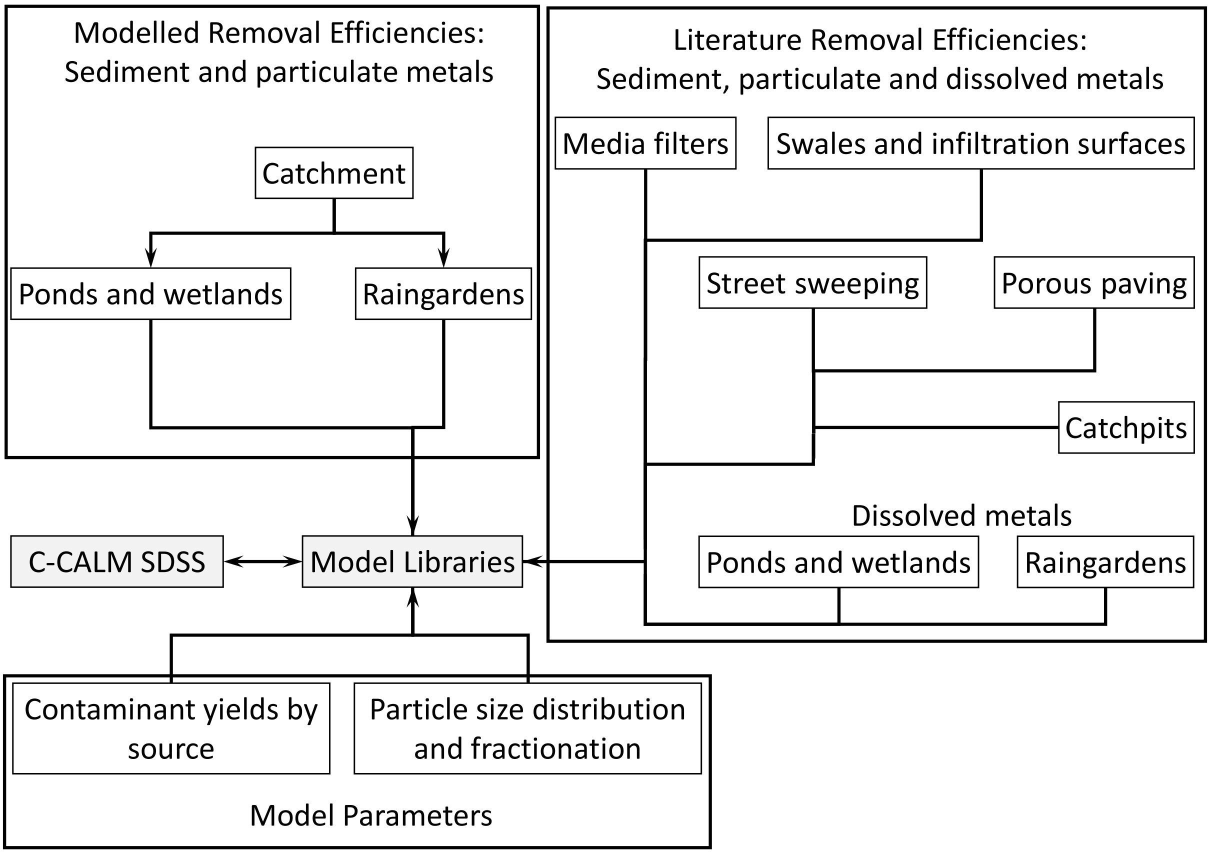


Figure 2-2: C-CALM model libraries for performance rules and model parameters are linked to the SDSS to provide flexible simulation of water treatment.

2.3 Spatial representation

While C-CALM does offer spatial analysis at the catchment level, like CLM, the model is lumped (i.e., not spatially distributed) within each SMU. Quasi-spatial distribution can be achieved by users supplying information on the proportion of each land cover that is served by a particular treatment option; that is, when a treatment option is inserted, a dialogue box opens which asks users to supply information about the type and proportion of surface it treats as well as the device design and the expected level of treatment.

C-CALM amalgamates like treatment devices into representative treatment options. Thus, in a catchment where arterial roads are treated with a series of filter chambers, treatment would be represented by a single filter treating the proportional catchment area covered by the corresponding road class. Elliott et al. (2006, 2009) showed, using successively simplified representations of stormwater treatment in the MUSIC model (Cooperative Research Centre for Catchment Hydrology, 2005), that treatment devices designed according to the same criteria for contributing areas with similar flow characteristics can be aggregated with little change to concentration and load calculations. Their work was undertaken as part of the LIUDD project and led to the decision to aggregated treatment in C-CALM. The US EPA SUSTAIN model (Shoemaker et al., 2009) allows a similar aggregation of model treatment elements.

Treatment networks are built-up by linking options so that the contaminants remaining after up-stream treatment are fed as input into the next option in the network. Each treatment in the option therefore has user defined sources entered into the dialogue box (i.e., land cover classes) and up-stream loads as modified by earlier linked treatment options.

2.4 Partitioning and fractionation

Sediments in stormwater contain a wide range of particle sizes with an associated range of settling speeds (see reviews in Roesner et al., 2007; Semadeni-Davies, 2013). Factors such as land use and the soil type in a catchment affect these particle sizes. Sediments in C-CALM are divided into five default particle size distributions (PSDs); these are denoted fine, medium fine, medium, medium coarse and coarse (Table 2-2), and cover the range of PSDs found in stormwater.

The five PSDs are defined according to nine common size classes. The selection and representation of the five C-CALM PSDs is discussed in detail in Semadeni-Davies (2008a), Semadeni-Davies (2008b) and Harper et al. (2008). The medium PSD is based upon the results of the US National Urban Runoff Program (NURP, Driscoll et al., 1986). The NURP fall speeds were scaled down by factors of ten and two respectively for the fine and medium fine PSDs, and up by factors of ten and two respectively for the coarse and medium coarse PSDs. Particle diameter is calculated from the fall speed (and vice versa) using Stokes' law for particles with a diameter < 100 µm, or Rubey's equation. Particle densities used in the calculations were adapted from the MUSIC model (Cooperative Research Centre for Catchment Hydrology, 2005) and vary with particle size.

Having the PSDs defined according to common size classes means that sediments from different sources can be added together in a treatment train. Coarse sediments are removed preferentially as treatment progresses along the train. This is reflected in C-CALM by having different treatment efficiencies for the different size classes in the performance rules for ponds, wetlands, catchpits and street sweeping. C-CALM routes each sediment size class through the treatment options separately and then calculates the SMU sediment load as the sum of the sediment remaining after treatment in each size class.

Metal partitioning and fractionation is complex and depends on the physical and chemical properties of sediments (e.g., source material, surface area, texture, porosity) and stormwater (e.g., pH). Moreover, partitioning and fractionation can change with distance from the source due to processes such as settling, dissolution and absorption. The processes involved are discussed with respect to C-CALM in (Semadeni-Davies, 2008a). The default C-CALM partitioning of metals into particulates is as follows:

For all roof types:
Particulate metal = 0.05 x Total metal

For all road types and paved surfaces:
Particulate metal = 0.6 Total metal

For all other (permeable) surfaces:
Particulate metal = 0.95 Total metal

Particulate metals are divided evenly into the same size classes as TSS, and removal calculations are made accordingly. The partitioning for roads and paved is based on a statistical analysis of total and particulate zinc and copper median concentrations found in untreated road runoff data collected from around the country. These data are held in the

Urban Runoff Quality Information System underlying database (Gadd et al., 2013; Gadd et al., 2014). The partitioning for roofs and permeable surfaces were extrapolated from analysis of Auckland stormwater.

Fractionation studies cited in in Semadeni-Davies (2008a) show conflicting results: while most studies report that the highest metal contents are associated with fine particles, others report that the highest metal contents are associated with larger sediments, especially where the grains have high porosity or where the PSD is coarse. Because of this apparent ambiguity, C-CALM adopts the pragmatic assumption that particulate metals are distributed evenly over all grain size classes.

2.5 C-CALM performance rules

Removal of contaminants conveyed in stormwater through stormwater treatment is dependent on a myriad of different factors, each of which are highly heterogeneous both spatially and temporally, so that there is no constant for the removal efficiency of a particular treatment option. Rather than modelling the stormwater network explicitly, for each treatment option, C-CALM queries a library of performance rules which have been derived from literature or modelling depending on the option. The development of these performance rules is detailed in Semadeni-Davies (2008b) for wetlands, ponds and raingardens and Semadeni-Davies (2008a) for the other treatment options. The use of query libraries is not without precedence in urban planning for stormwater and wastewater management, and there have been several examples over recent years (e.g., Martin et al., 2007; Makropoulos et al., 2008; Scholes et al., 2008). The libraries allow model simplification and the addition of tacit knowledge from a variety of stakeholders, particularly with respect to the relative performance of stormwater control options.

The original intention was to provide C-CALM with a set of performance rules that had been developed using continuously run conceptual models of the treatment options to determine the long-term level of treatment under a range of device designs and catchment conditions. This approach would enable C-CALM to have a sound theoretical modelling basis without the complexity, data and user expertise required of operational urban drainage models. However, New Zealand high quality data suitable for model development and testing proved to be difficult to obtain. Continuous data suitable for modelling was available from NIWA and Landcare Research to allow model development and testing for sediment (and associated metal particulate) removal from ponds (settling) and raingardens (filtering); settling from wetlands has been assumed to be the same as for ponds (Semadeni-Davies, 2008b).

Out of necessity, the removal efficiencies of other treatment options were based on published values. Similarly, removal efficiencies for dissolved metals from ponds, wetlands and raingardens cannot be simulated using a generic method due to the complexity of the processes involved, and have also therefore been derived from the literature (Semadeni-Davies, 2008a). The literature based performance rules are given in Appendix B.

In addition to the performance rules, C-CALM also includes a generic treatment option which allows users to enter known removal efficiencies for a specific treatment option (e.g., derived from monitored data) or removal targets for each contaminant in increments of 5%.

Table 2-2: C-CALM particle size distributions as defined by the percentage of particles in nine common size classes.

Class	Particle diameter (μm)	Fall speed (m h^{-1})	Density* (kg m^{-3})	Percentage of particle mass in size class				
				Fine grain	Medium grain (NURP)	Medium fine grain	Medium coarse grain	Coarse grain
1	1.5	0.001	1300	11.72	0	0	0	0
2	3	0.005	1300	15.11	2.47	9.2	0	0
3	6	0.04	1600	22.6	22.4	22.7	17.4	0
4	12	0.25	1900	19.5	19.3	19.5	19.3	19.3
5	24	1.47	2300	19.1	18.9	19.1	18.9	18.9
6	48	6.77	2500	11.9	16.5	16.7	16.5	16.5
7	96	29.8	2650	0	16	12.8	16	16
8	192	89.80	2650	0	4.47	0	11.9	11.9
9	380 and greater	198.23	2650	0	0	0	0	17.38

* Densities adapted from MUSIC (Cooperative Research Centre for Catchment Hydrology, 2005)

2.5.1 Performance rule development: modelling

The creation of the modelled performance rules for ponds / wetlands and raingardens has entailed three tasks:

1. Development and testing of continuous conceptual models of overland flow and contaminant transport for a range of catchment types
2. Development and testing of continuous treatment models for ponds / wetlands and raingardens.
3. Multiple model runs over a 10-year simulation period with regional input data (i.e., rainfall and evapotranspiration) and unique parameter sets to simulate the range of device design in order to determine the effect of different stormwater control options on long-term removal efficiencies.

Given that the purpose of the models was to provide a means of creating a treatment library, the routines were simplified with few calibration parameters. All of the models have a 5-minute time-step. Full details on model development and testing can be found in Semadeni-Davies (2008b) and Harper et al. (2008). Sensitivity analyses which evaluate the relative impacts of input data and parameter choice on the performance rules can be found in Semadeni-Davies and Harper (2008).

Catchment modelling

The catchment model couples a hydrological rainfall / runoff model (double-linear reservoir for soil infiltration, storage and percolation, and kinematic wave for overland flow over impervious surfaces) to sediment accumulation and wash-off equations for impervious surfaces (Butler and Davis, 2010). The purpose of the model was to provide inflows of water and sediment to the treatment models outlined below. The catchment model has been tested on stormwater flows and sediment sampling from three urban catchments with varying areas and land use; these are Mission Bay (residential), Auckland CBD (commercial) and Tamaki (industrial).

Pond / wetland settling model

The settling model couples a continuity equation for the pond water-balance coupled to equations for quiescent and dynamic settling (continuously stirred tank reactor model, e.g., Driscoll et al., 1986) to simulate flow and water treatment. Wetlands are treated in the same way as ponds, albeit with greater hydraulic efficiency (see Appendix D). The model has been tested on two stormwater ponds (Silverdale and Te Atatu).

Once tested, the catchment and settling models were run continuously with a simulation period of ten years to obtain long term removal efficiencies for inclusion in the query library. Each model run represents a unique combination of parameters from an input parameter set. The set of results from all possible parameter combinations defines the performance rules in the query library for ponds / wetlands. The input parameter set is given in Table 2-3; there are 388,800 possible combinations, 48600 runs per region, and within each region, 16200 runs per land use category. The removal efficiency ranges from around 30% to 100%, which is consistent with reported values internationally (e.g., Schueler, 1992; BMP database, 2012). Three examples of pond / wetland performance rules are given in Figure 2-3.

Table 2-3: Parameter set for generating the performance rule library for settling ponds and wetlands in C-CALM.

Catchment Parameters:	
Region:	Auckland / Northland / Waikato Bay of Plenty / East Cape / Hawke's Bay Taranaki / Manuwatu Wellington / Tasman / Marlborough, Canterbury Otago / Southland West Coast
Land use (i.e. build-up and wash-off rates) and impervious percentage of surface area:	Residential – 20%, 40% and 60% Commercial – 60%, 75% and 90% Industrial – 60%, 75% and 90%
Average gutter slope:	0.005, 0.01, 0.03 and 0.05
Pond (and Wetland) Parameters:	
Specific area: (ratio of wet surface area relative to the area contributing impervious surfaces))	50, 100, 150, 200 and >250 m^2/ha expressed as fractions: 0.5, 1, 1.5, 2 and 2.5
Invert level:	0.5, 1.0 and >1.5 m
Width (or width equivalent) of outlet weir:	1, 2 and 3 m
Extended detention:	Yes, or no (if yes, slot weir width is set to 10% of the outlet weir width, depth = 30cm)
Hydraulic rating: (see Appendix D for guide)	1 (poor), 3.5 (good) and 8 (excellent)
PSD	Fine, medium fine, medium (NURP), medium coarse, and coarse

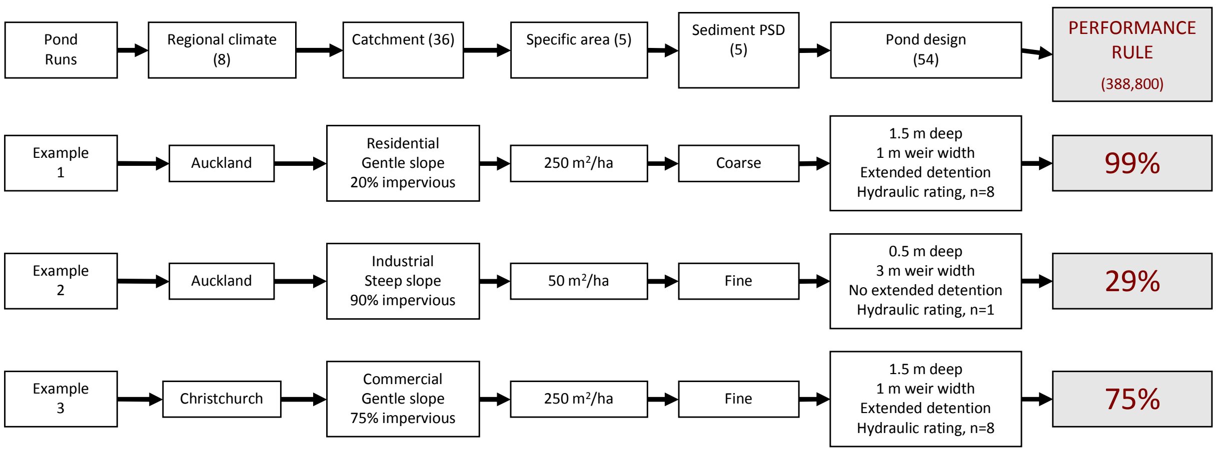


Figure 2-3: Examples of performance rules for pond/wetlands showing how parameter choice (e.g., climatic region) affects removal efficiency (% removal). The values in brackets are the number of choices for each parameter type.

Raingardens and bio-retention units

Raingardens and bio-retention units are modelled by water-balance (double linear reservoir) coupled to an empirical time-based contaminant depletion equation. It is assumed that inflow is from impervious surfaces only. The removal equation was derived from the MUSIC model (Cooperative Research Centre for Catchment Hydrology, 2005) and assumes that the removal rate is the same irrespective of grain size. While fine sediments are likely to have a lower removal rate than coarse ones, the C-CALM raingarden model does not attempt to simulate this due to both the complexity of the processes involved and the lack of supporting data. However, users are asked for the PSD range to allow sediment routing to other treatment options. The module has been tested on data from the Waitakere Vehicle Testing Station raingarden, collected by NIWA for the Auckland Regional Council (Skeen and Timperley, 2008). Bio-retention units are assumed to have the same removal efficiency as raingardens with the difference in removal due to scale.

The parameter set which defines the performance rules in the query library for raingardens is given in Table 2-4. The number of model runs for the raingarden model is 69120; 8640 runs per region, and within each region 2880 runs per land use category. The removal efficiencies range from 25-95%, with the least performing raingardens being those that are relatively small with by-pass. For raingardens with no by-pass drainage, the lowest removal efficiency simulated is 60%. The upper simulated efficiency values are consistent with the findings from the United States (Davis et al., 1998; Davis et al., 2003). Trowsdale and Simcock (2011) found that a raingarden in Auckland was able to reduce sediment and zinc concentrations by considerable amounts (orders of magnitude for zinc), however the raingarden acted as both a source (possibly due to the presence of fungicides) of copper. The International BMP database reports a high range of efficiencies for bioretention (BMP database, 2012). Examples of performance rules for the removal of TSS and particulate metals in raingardens are given in Figure 2-4.

Table 2-4: Parameter set for generating the performance rule library for raingardens in C-CALM.

Catchment Parameters:	
Region:	Auckland / Northland / Waikato Bay of Plenty / East Cape / Hawke's Bay Taranaki / Manuwatu Wellington / Tasman / Marlborough, Canterbury Otago / Southland West Coast
Land use (i.e. build-up and wash-off rates) and impervious percentage of surface area:	Residential – 100% Commercial – 100% Industrial – 100%
Average catchment slope:	0.005, 0.01, 0.03 and 0.05
Raingarden (or Bioretention Unit) Parameters:	
Specific area: (ratio of raingarden surface area relative to the contributing area)	100, 200, 400 and 600 m^2 /ha1 expressed as fractions: 1, 2, 4 and 6
Depth:	0.5, 1.0 and 1.5 m
Bypass:	Yes, or no (if yes, generic parameters for the bypass outflow weir)
Deep percolation to groundwater:	0% (isolated from groundwater), 10%, 20%, 40% and 50%
Media median grain size (diameter)*	0.5 mm (medium sand), 1 mm (coarse sand), 2 mm (very coarse sand), 3 mm (gravel - e.g. pumice soils)

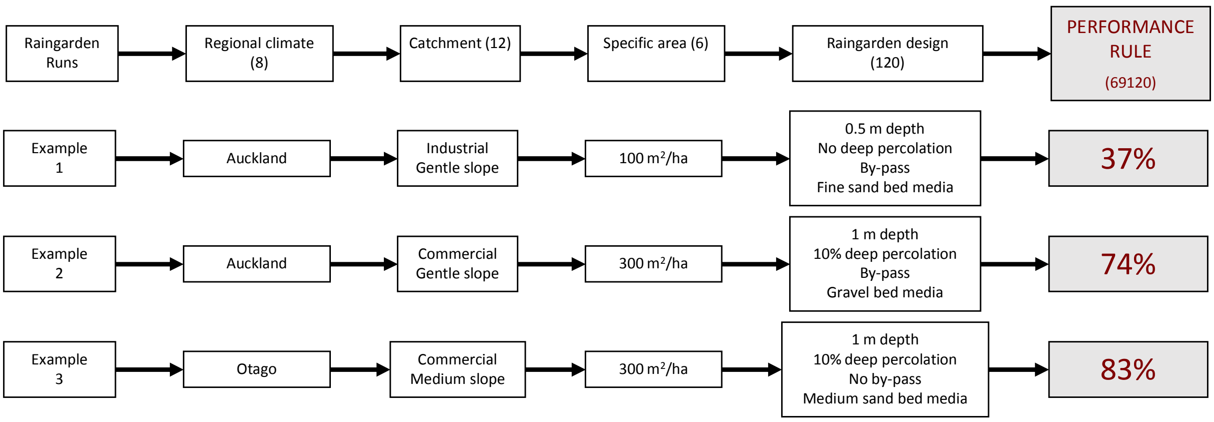


Figure 2-4: Examples of performance rules for raingardens showing how parameter choice affects removal efficiency (% removal. The values in brackets are the number of choices for each parameter type.

2.5.2 Performance rules development: literature

The literature based rules for the removal of dissolved metals in ponds/wetlands and raingardens, and water treatment for TSS and metals using other treatment options were derived from a review of both local and international case-studies (Semadeni-Davies, 2008a). It was found that the removal efficiency of a particular stormwater treatment option is highly site- and event-specific, and depends on the environmental drivers at the site (land use, geology, topology, topography hydrology and climate), water chemistry (e.g., pH) and the type and design of the treatment facility. However, most of the studies cited do not contain information on the wider environment or sediment properties (e.g., PSD) and many were laboratory based, particularly for filters, which means that they may not be representative of field conditions. Therefore, C-CALM provides users with a choice of high, medium or low efficiency, specific to each treatment option that can be chosen from a drop down menu in the option dialogue box. That is, users are asked to select the appropriate level of treatment according to *a priori* knowledge of local design criteria, device type and configuration and catchment conditions. Where possible, sediment removal efficiency has been related to sediment size (i.e., street sweeping and catchpits) – all other options assume equal removal efficiency for all sediment size classes.

The derivation of performance rules for filters is given below as an example of literature based rules. The rules for filters and other treatment options are given in Appendix B. The efficiency of a filter depends on both the retention time and the type of medium in the filter bed. The retention time is determined by the inflow rate, the dimensions of the filter bed and the porosity (i.e., storage capacity and hydraulic conductivity) of the medium. There are two main treatment processes in filters, mechanical removal of sediments (related to the size of the sediments relative to the pore spaces of the filter media) and chemical sorption of dissolved contaminants. A third removal process is precipitation as dissolved contaminants react with the filter medium to produce particles which can be filtered by the medium. Filter media are many and varied. They can also be activated with a sorbent material added to provide chemical as well as physical removal. The choice of medium should be made with reference to the target contaminant. Sand, which is cheap and readily available, continues to be a common medium in New Zealand. Other media that have been used or tested for stormwater and road runoff treatment are zeolite, perlite, activated charcoal / carbon, wood and bark, fly-ash, peat, compost, moss, iron slags and gravel. Media can also be mixed or arranged in layers to treat different contaminants in stormwater, for example, CPZ (activated carbon, potassium permanganate and zeolite) is able to remove TSS and particulate contaminants as well as dissolved metals.

Most of the studies evaluated by (Semadeni-Davies, 2008a) assessed removal efficiency using laboratory column tests. Table 2-5 is a summary of selected literature while Table 2-6 extends this information into performance rating categories for filters. Note that the literature gives a variety of removal efficiencies which relate to different experimental design and filter configurations. Providing high, medium and low performance expectations means that C-CALM can be used to simulate, for example, the difference between a sand filter (low to medium removal) and a proprietary filter with an activated media bed (medium to high removal).

Table 2-5: Selected summary of reported removal efficiencies (% removal) for media filters. From Semadeni-Davies (2008a).

Contaminant	Study and media tested						
	ARC (2003) Sand	Färm (2002) Zeolite and opoka	Hatt et al. (2007) Gravel	Taylor (2006) Slag	Nanbakhsh et al. (2007) Soil	Pandey et al. (2005) Sphagnum moss and wood ash (lab)	Taylor and Pandey (2005) Sphagnum moss and wood ash (field)
TSS	75	-	-	-	66-70	-	93
TCu	75	-	62	-	-	-	90
Dissolved Cu	-	38-89	-	85-96	-	>94	-17
TZn	75	-	38	-	-	-	64
Dissolved Zn	-	53-97	-	48-98		>94	24

Table 2-6: C-CALM performance rules (% removal) for media filters. From Semadeni-Davies (2008a).

Performance rating	TSS and particulate metals*	Dissolved Cu	Dissolved Zn
Low	60	40	20
Medium	75	70	60
High	95	95	95

*The removal efficiency is assigned to all sediment size classes

A subsequent independent evaluation of three *in situ* proprietary filters undertaken by NIWA for the New Zealand Transport Agency (Moores et al., 2012) found that the filters tested achieved different levels of stormwater treatment and that the removal efficiency for filters varied widely from event to event. The removal efficiency of TSS and dissolved copper was generally low (average removals were 17, 46 and 65% for TSS; 26, 12 and 50% for dissolved copper) while removal of dissolved zinc was in the low to high range (83%, 23% and 66%) for the three filters respectively. These results reinforce the need for users to be aware of the type of filter being used, the filter medium and whether the filter is adequately sized for the flow volume. Users also need to be aware that the removal efficiency for one contaminant does not imply the same level of treatment for the other contaminants.

2.6 Representing SMU stormwater treatment

C-CALM is a semi-distributed model, that is, the model operates at the SMU or sub-catchment level with spatial data lumped within each SMU. Users are asked to supply the fractional area of each SMU covered by each land cover class and the proportion of runoff from each class that is served by each treatment option.

Treatment trains can be simulated by C-CALM with the caveat that C-CALM does not simulate surface flows or device hydraulics so that the effects of storage and attenuation on treatment are not taken into account. Trains are built by linking options so that the contaminants remaining after up-stream treatment are added as input into the next option in the network. Each treatment option in the train has user defined sources entered into the dialogue box (i.e., land cover classes) and up-stream loads from earlier linked treatment options.

Removal of dissolved metals by trains is calculated as the total load entering the train reduced by the removal efficiency of each treatment option in turn. As stated in Section 2.4, for sediments, C-CALM routes each sediment size class through the treatment network separately and then calculates the SMU sediment load as the sum of the sediment remaining in each size class after treatment. Particulate metals are divided evenly into the TSS size classes and removal calculations are made in the same way.

As was stated above, having a range of sediment size classes means that removal of sediments in a train can be modelled more realistically than with a single sediment removal calculation. For example, a pond which treats road runoff from an area treated with catchpit inserts will receive a reduced load of coarse sediments compared to a pond receiving road runoff with no pre-treatment. The CLM load reduction factors for catchpit inserts and wet ponds (road runoff) given in Timperley et al. (2010) are 20% and 75% respectively giving a combined TSS removal of 80% (i.e., 20% initial removal by catchpit inserts followed by 75% removal of the remaining sediment reaching the pond). The comparable calculations for C-CALM, assuming a fine PSD and a large pond with a high hydraulic rating, are given in Table 2-7. It can be seen that the estimated removal efficiency is less (74%). In contrast, the same train treating road runoff with a medium PSD would give a total removal of 88%, while treatment of coarse sediments in the same pond would result in 98% TSS removal. The removal efficiency would also decrease with pond size and hydraulic efficiency.

Table 2-7: Hypothetical example of sediment removal calculations for a treatment train treating road runoff. The train consists of catchpits with inserts followed by a detention pond. The initial sediment load is 1 kg with a fine PSD.

Band	Initial sediment mass (g)	Catchpit removal (%)	Remaining sediment mass (g)	Pond removal* (%)	Remaining sediment mass (g)
1	117.2	0	117.2	39.3	71.2
2	151.1	0	151.1	42.4	87.1
3	226.4	0	226.4	60.7	89.0
4	195.2	0	195.2	91.8	16.0
5	191.1	0	191.1	99.4	1.1
6	119.0	20	95.2	99.6	0.4
7	0.0	60	0	99.6	0
8	0.0	80	0	99.6	0
9	0.0	90	0	99.6	0
Total	1000.0		976.2		264.8

*Region – Canterbury
Catchment parameters: residential land use, gentle slope, impervious surfaces = 60%
Pond parameters: invert level = 1.5 m; specific area =250m^2/ha; weir width = 1m; extended detention, hydraulic rating = 8

3 C-CALM Installation and Interface

3.1 Model requirements

C-CALM is supplied as a dynamic-link library (.dll) for ArcMap 10.1 and includes a database containing yields and the performance rule query library. Users must have administrative privileges to install C-CALM

C-CALM requires .NET Framework 4.0 or later to be installed (this manual was prepared using .NET 4.5.1), the framework can be downloaded from Microsoft (http://www.microsoft.com/en-nz/download/)

The minimum data requirements for C-CALM are SMU boundaries and the proportion of the SMUs covered by each of the land covers listed in Appendix B (this information is added using an Excel spreadsheet template supplied with C-CALM).

3.2 C-CALM database

C-CALM is provided with a relational geo-database (*dbccalm.mdb*, this can be viewed using MS Access) which holds the following information:

- Performance rule query library for all treatment types - separate tables are provided for the modelled and literature-based sets of rules;
- Region – determines which set of modelled performance rules is used with respect to location of the catchment shape file supplied by the user;
- Land cover types available and their annual sediment, copper and zinc yields (see Table 2-1);
- Particulate metal partitioning and fractionation (see Section 2.4); and
- PSDs and grain size classes (Table 2-2);

The database also holds the model set-up so that treatment options which have been placed in a catchment will remain in place for subsequent modelling sessions. Removal of treatment options from the database is discussed in Section 4.5.

The database can be updated for local information (e.g., removal efficiencies, yields, PSD, fractionation), however users are required under the C-CALM licencing agreement (Appendix A) to contact NIWA for approval before changes are made to the database.

3.3 C-CALM shape files

C-CALM uses New Zealand Transverse Mercator 2000 (NZTM2000) projection.

C-CALM is supplied with a national coastal shape file split into regions (nz_regions). This shape file is used to determine the region for the query library and to aid display of results.

Users are required to supply a SMU or sub-catchment polygon shape file which C-CALM uses to define the boundaries of the sub-catchments to be simulated. The shape file must have a field which identifies each SMU numerically (short integers). Users are also able to include fields for their own information for displayed within ArcMap.

Land use data is entered into C-CALM using an Excel spreadsheet.

Upon entering the required spatial data, the following shape files are automatically created and displayed by C-CALM:

- *ccalm_units*
  Polygon shape file – created from the user supplied SMU shape file. Each SMU is expressed as a separate model unit with the same numerical identifier (SMU_ID) as the user supplied shape file. The length, width and area of each model unit are calculated and listed in the attribute table. The shape file also has the same attribute fields as the original SMU shape file.

  Selecting the shape file in the *TOC* will activate the treatment options on the interface.

- *fcDevices*
  Polygon shape file – displays the treatment options available. This shape file is displayed only after a treatment option is selected on the interface. The shape file must be selected in the *TOC* to link treatment options and run the model.

- *fcLinks*
  Line shape file – displays user defined links between treatment options (i.e., treatment trains). This shape file is displayed only after the links icon has been clicked.

  Note that even if no links are created by the user, C-CALM requires the link icon to be clicked before running.

The model results are held in a group layer (*Outputs*) which displays model results for the simulated catchments by contaminant after running C-CALM. Users can select which set of results to display and can alter the symbology according to their own requirements. The data displayed in the *Outputs* group layer is stored in the database and is updated after each model run.

3.5 Installing C-CALM:

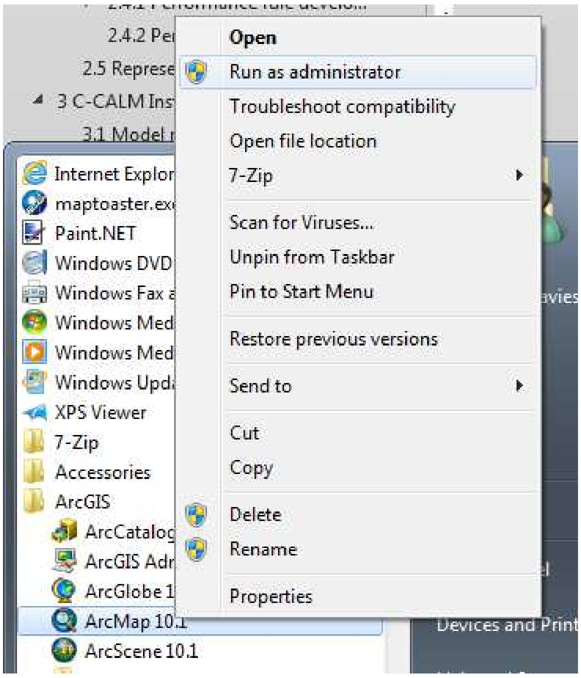
C-CALM requires administrative privileges to install.

1. Ensure ArcMap is closed.

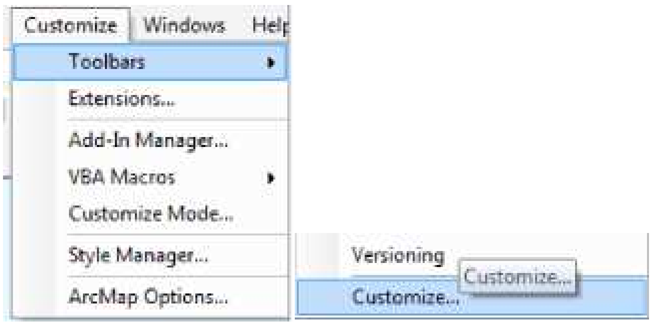
2. Copy the folder C-CALM_2.0 directly into your C drive. Check you have the following:

   - the C-CALM dll folder
   - the land cover entry template spreadsheet landuse.xlsx
   - the geospatial database dbccalm.mdb

3. Open ArcMap as an administrator (right click on ArcMap under the Start Menu and login) with a blank map. Once C-CALM is installed, ArcMap can be run normally.

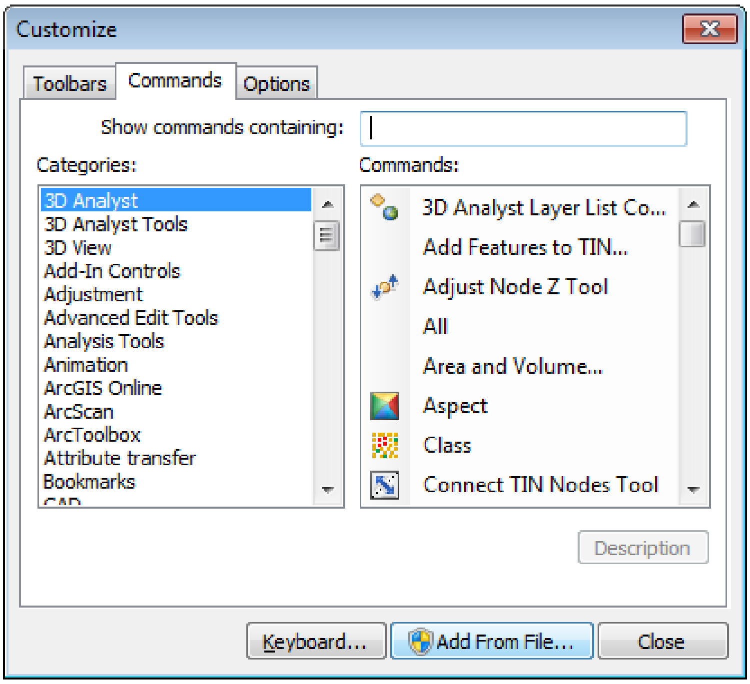


4. Click on *Customize* and select *Customize* from the *Toolbars* menu



   This will open the *Customize Toolbars* window

5. Click on the *Add From File* button under the *Command* tab and navigate to the C-CALM dll folder. Select *ccalm_2.tlb and click OK*


Customize
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ArcScan
ArcToolbox
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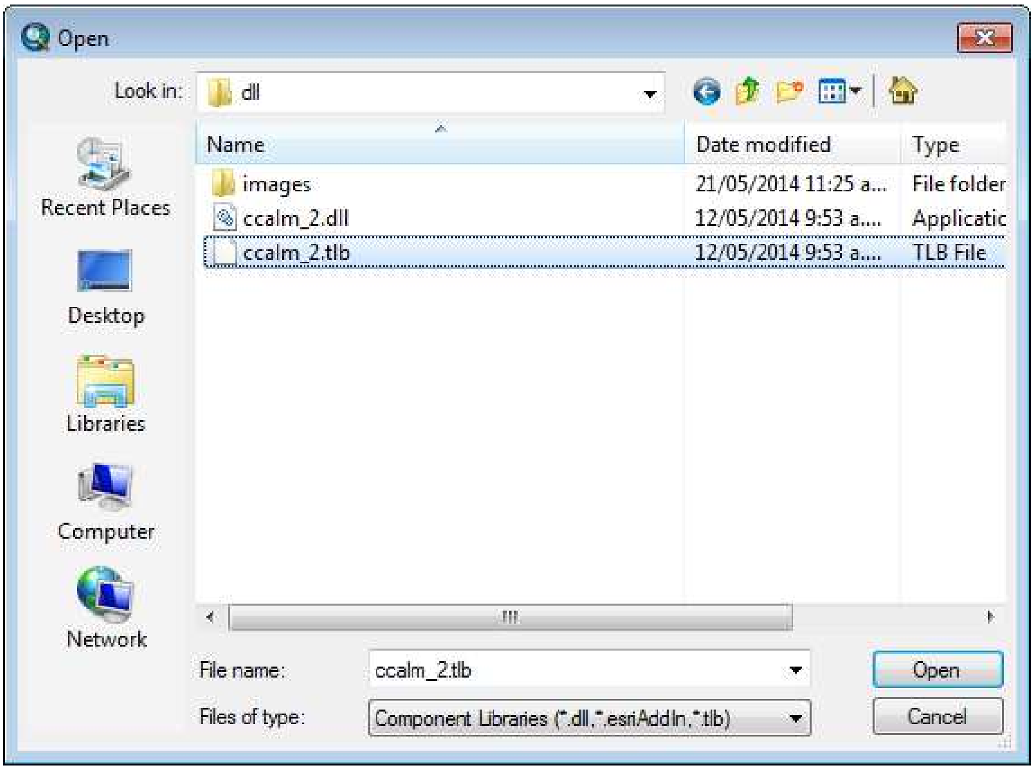
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12/05/2014 9:53 a....
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ccalm_2.tlb
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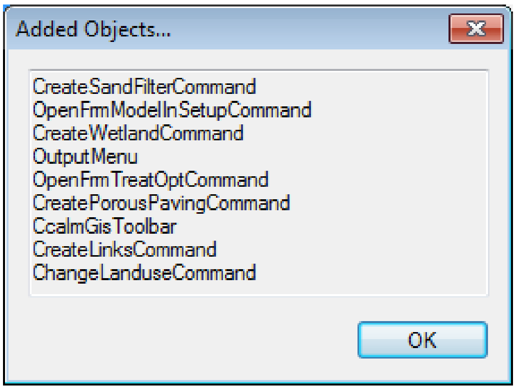
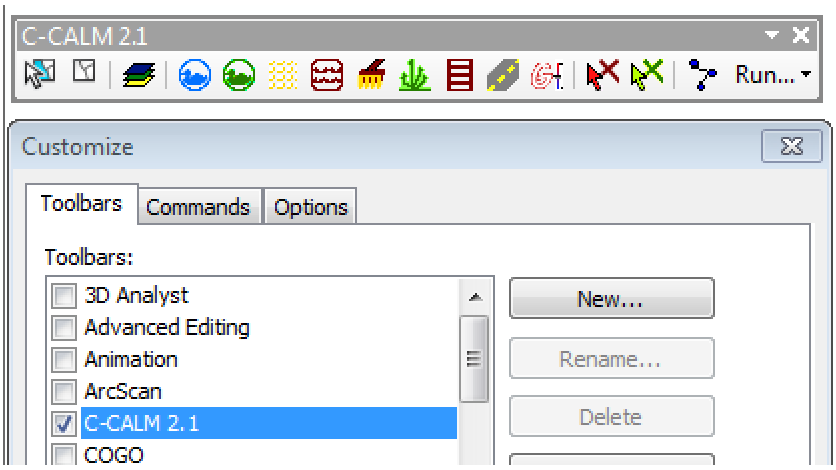


6. Click on the Toolbars tab, C-CALM should be listed, once checked, the C-CALM toolbar will be displayed.



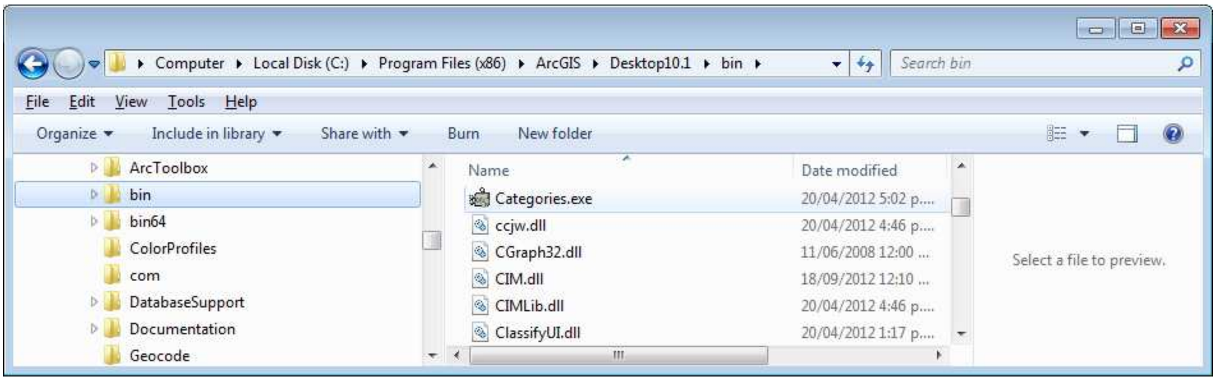
3.6 Uninstalling and deregistering C-CALM

C-CALM will need to be uninstalled and deregistered prior to installing an updated version of the model.

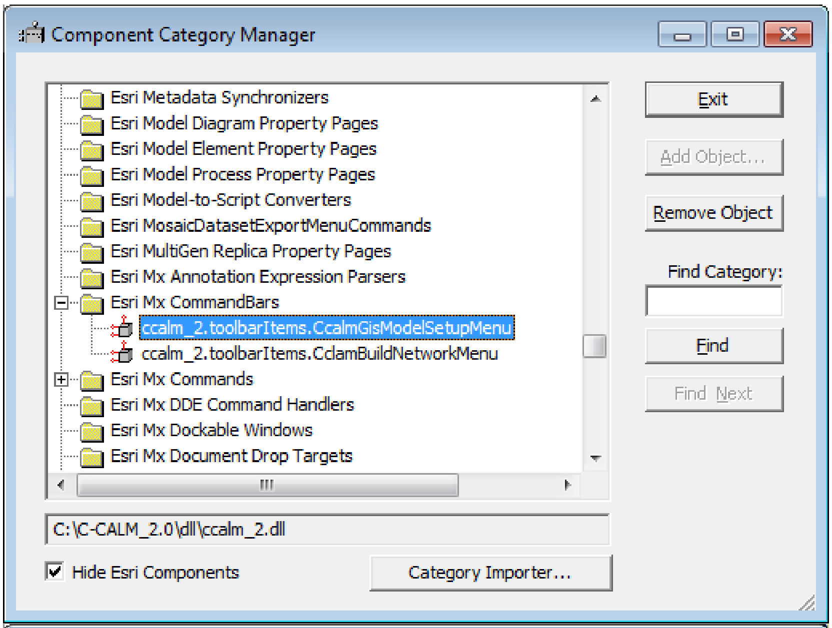
1. Open ArcMap as an administrator and uncheck C-CALM from the *Customize Toolbars* window. Close ArcMap

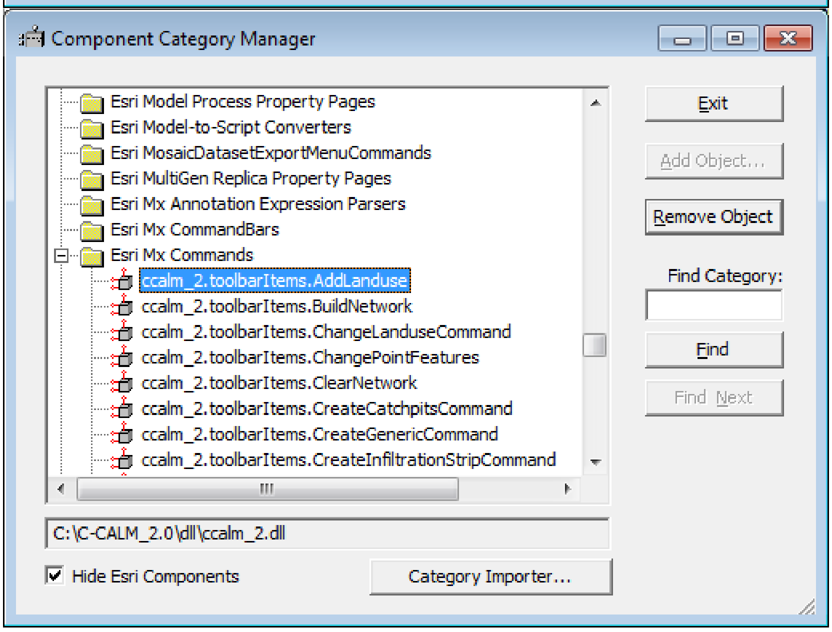
2. Navigate to the ArcGIS program folder *ArcGIS\Desktop10.1\bin* and open the *Categories.exe* executable file as an administrator

   C:\Program Files (x86)\ArcGIS\Desktop10.1\bin



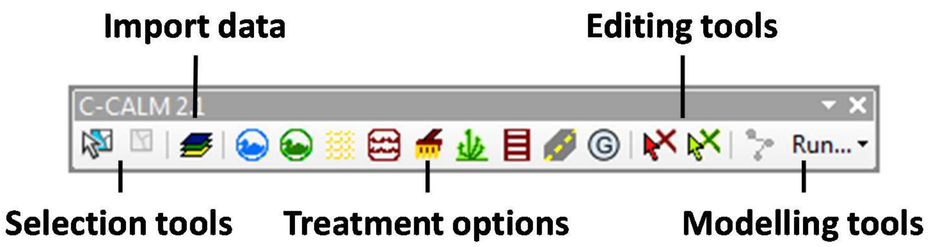
3. Remove all traces of the C-CALM toolbar from ESRI MX CommandBars and ESRI MX Commands. Close Categories.exe.





3.7 The C-CALM interface

The C-CALM interface is displayed as a tool-bar which is split into the following five sections: SMU selection tools; data importation; inserting treatment options; treatment editing tools; and modelling tools. The toolbar is show below (Figure 3-1) along with a description of the icons. Icons are greyed-out until they become activated as users complete the model set-up.



Interface section	Icon	Description
Selection tools		Select feature
		De-select feature
Import data		Import spatial data (subcatchment shapefile and land cover spreadsheet)
Treatment options		Wet detention pond
		Wetland
		Catchpit
		Filter
		Street-sweeping
		Raingarden / bioretention
		Infiltration strip / swale
		Porous paving
		Generic (user specified) treatment
Editing tools		Delete treatment option
		Edit treatment option
Modelling tools		Link treatment options
	Run…	Select run option
	build and run	Run C-CALM
	delete model inputs	Delete all treatment options and links

Figure 3-1: The C-CALM interface toolbar and icons.

4 Getting started

4.1 Test Case: Waiarohia Catchment

The shape files used in this manual are from the Waiarohia Inlet catchment between Whenuapai airbase and Hobsonville west of Auckland. The catchment is largely rural with a small area of residential land use. The catchment consists of 14 natural drainage sub-catchments which were used as the boundaries for SMUs in this manual. The land use in this manual has been set-up to illustrate the application of C-CALM and reflects neither the actual land use nor any planned development. Similarly, the treatment options simulated were chosen only to illustrate the use of C-CALM and do not represent actual or planned water treatment The sub-catchment boundaries and hypothetical land use as defined for this manual are mapped in Figure 4-1. The land cover fractions for each catchment and their treatment options are detailed in Appendix B.

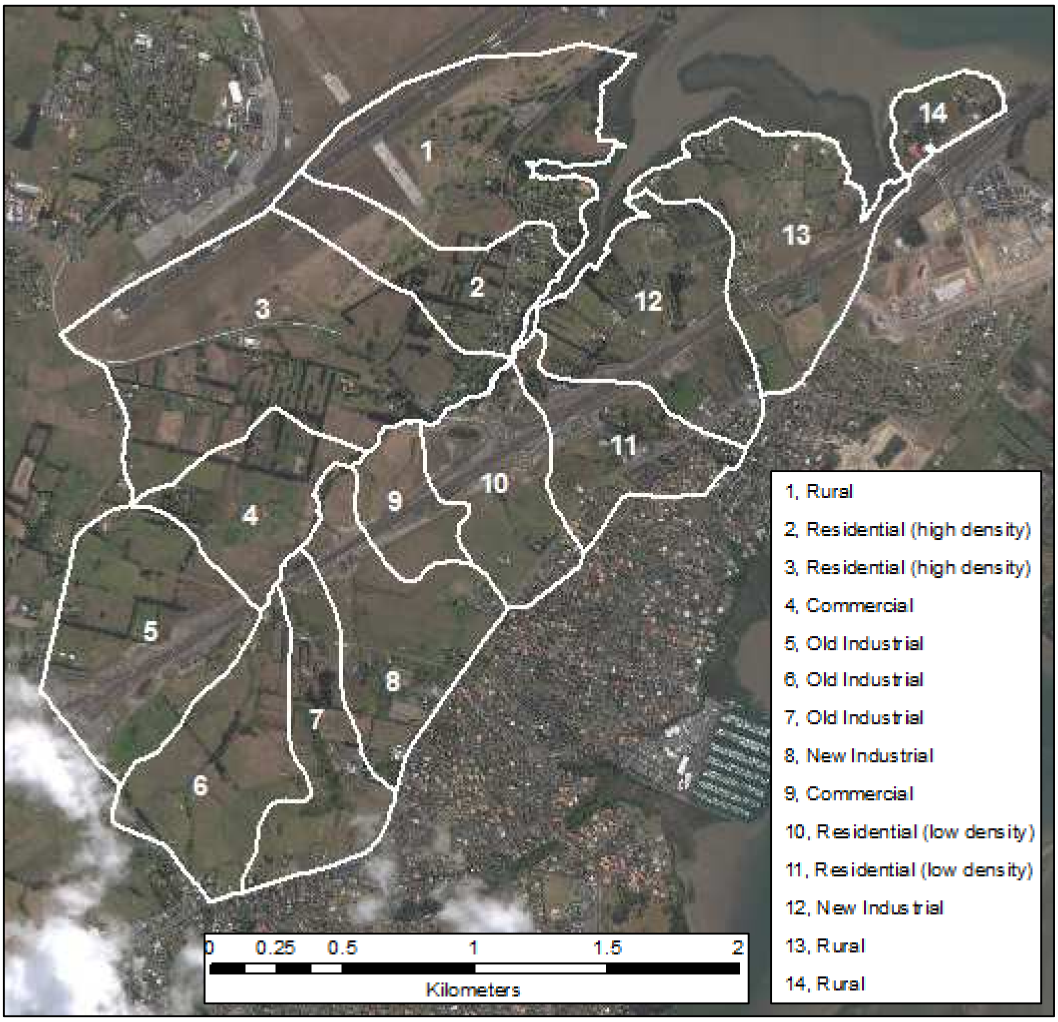


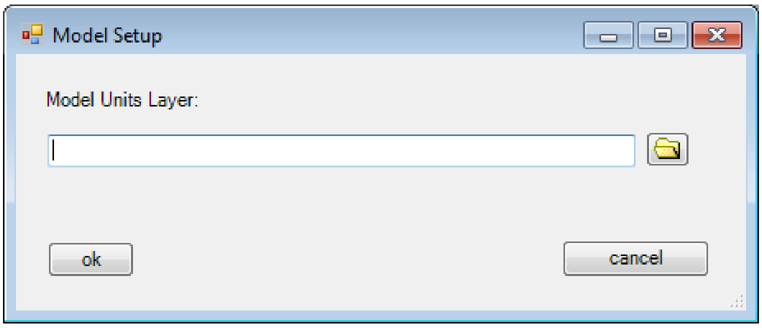
Figure 4-1: Hypothetical land use for the Waiarohia Inlet catchment. Note that the land use and treatment options given in this manual are intended to illustrate the use of C-CALM and reflect neither the actual nor planned land use nor water treatment options.

4.2 Importing spatial data

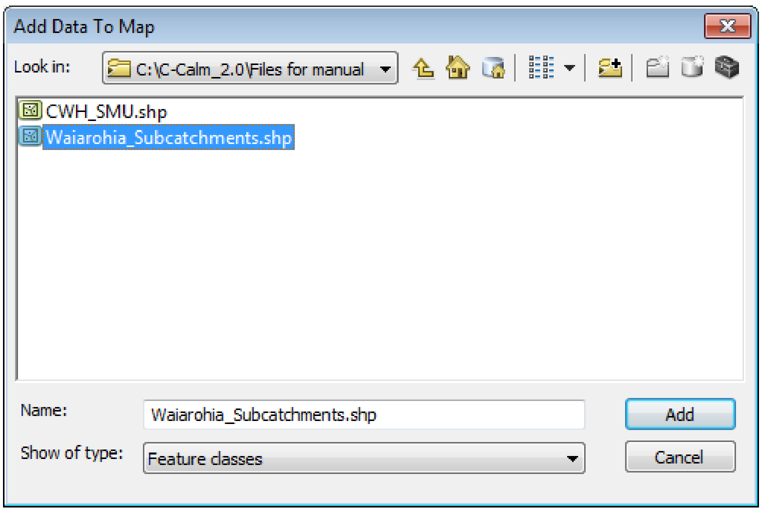
C-CALM requires SMU boundaries and land cover data to run. Currently, land cover data is entered using an Excel Spreadsheet template automatically generated by C-CALM. C_CALM must be run within a new blank map. While a map document saved with the C-CALM model shape files active will display these shape files and will run, the outputs map will not be registered or displayed and any changes made to land use will not be updated in the database. If you have other shape files you wish to display at a later date, save these as a map document first and then add in the *saved* model outputs for display after modelling is complete.

1. Open ArcMap and make sure the C-CALM toolbar is open. The icons will initially be greyed out with the exception of the *import data* button.

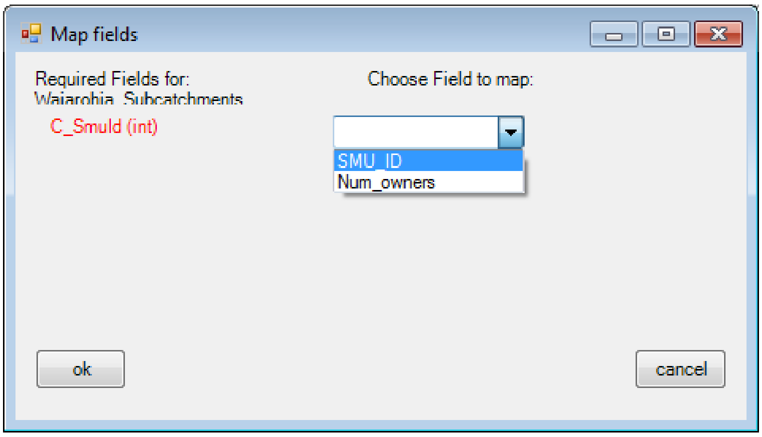
2. Click the *Import Data* button to open the *Model Setup* window.



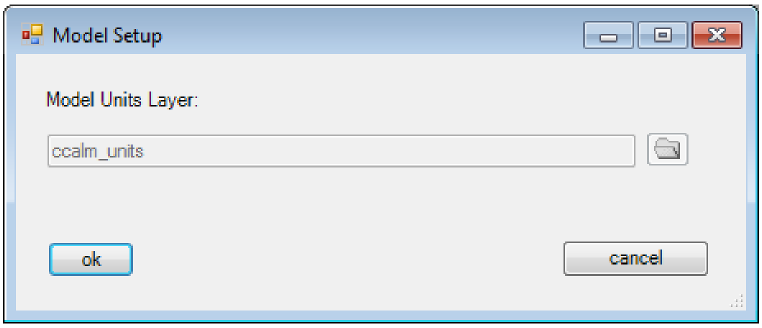
4. Browse to select and add the user supplied catchment boundary shape file (here Waiarohia_subcatchments.shp). This file must contain an identification field which numbers the SMUs (short integer). Select the shape file and click OK to create a new shape file called ccalm_units in the C-CALM geo-database. The ccalm_units shape file holds the same fields as the user supplied shape file.



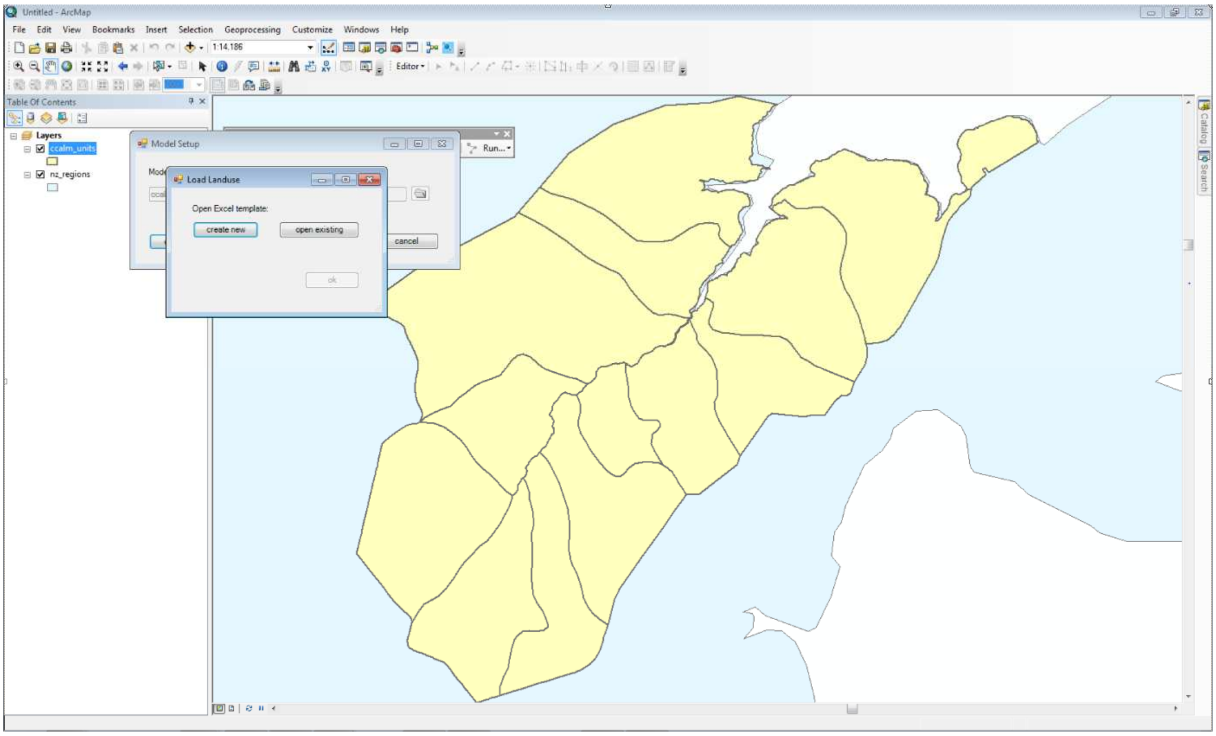
5. Adding the shape file will open the *Map Fields* window. Select the field for the user supplied shape file which holds the numerical identifiers for the SMUs. C-CALM will list only those fields which are defined as short integers (in the example below, there are two short integer fields; the identifier field is called SMU_ID). The identifiers will be assigned to a new field called C_SmuID in the ccalm_units shape file which is used by C-CALM. Click OK to return to the Model Setup window.



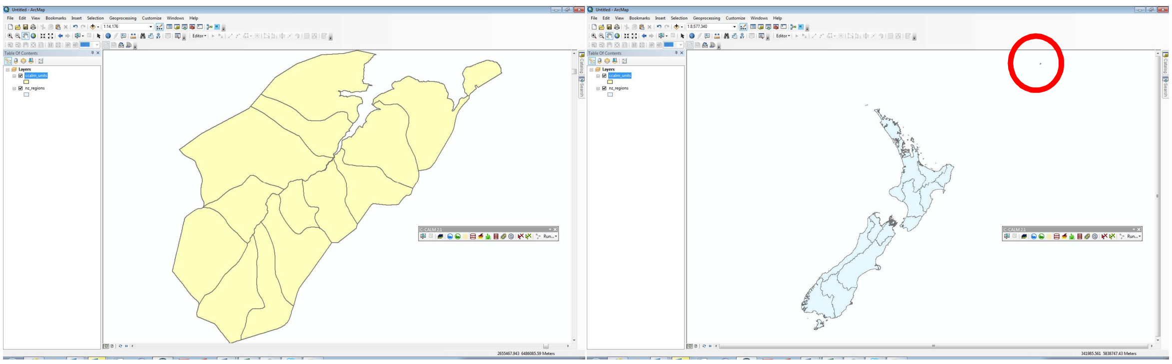
Click OK to return to the Model Setup window. The ccalm_units shape file has been created.



6. Click OK to open the load land use window. Instructions for loading landuse follow in Section 4.2.1. Note that the ccalm_units shape file is now mapped along with the nz_regions shape file and C-CALM has zoomed to the study area.



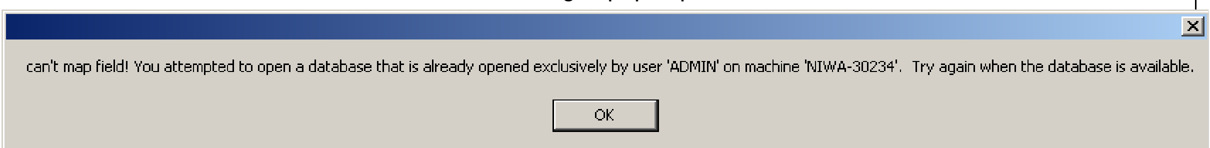
TROUBLE SHOOTING: The ccalm_units shape file has appeared, but I cannot see the coast line.



Check the projection of your input shape file. Here C-CALM is trying to map the ccalm_units shape file created from the input shape file projected with NZ Map Grid 1949 projection as NZTM2000.

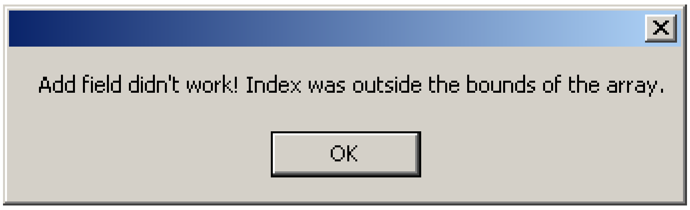
Use the in-built *Geoprocessing Toolbox (Data Management, Projections and transformations) Project* tool to transform the input shape file into a new shape file with an NZTM projection and restart C-CALM.

TROUBLE SHOOTING: When I click OK, this messages pops up:



The C-CALM database is not being updated for the new catchment shape file. This error can occur if you have recently had ArcMap open to edit the catchment shape file. You will need to exit ArcMap and restart the computer.

TROUBLE SHOOTING: When I click OK to add the ID field, one of these messages pops up:



The C-CALM database is not being updated. These errors tend to occur when a new blank document is opened without first closing ArcMap. Close and restart ArcMap and then follow the model set-up instructions above.

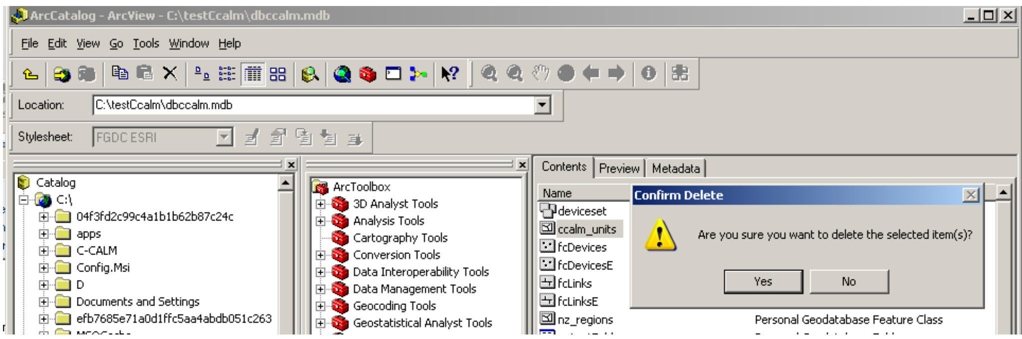
TROUBLE SHOOTING: When I click OK this messages pops up:

The C-CALM database is not being updated for the new catchment shape file. Clicking OK and continuing will bring up the catchment shape file from a previous modelling session. The update is normally automatic in C-CALM but may fail if you do not have MS Access on your PC, you may need to delete the old *ccalm_units* table manually before running C-CALM.

Click OK and close the Model Setup box by clicking the red close box. Then try uploading the shape file again. If the error recurs…

Close ArcMap and open ArcCatalog.

Browse to the database in the C-CALM folder (dbccalm.mdb).
Delete the *ccalm_units* shape file.



Close ArcCatalog and re-open ArcMap.

Follow the model setup instructions above.

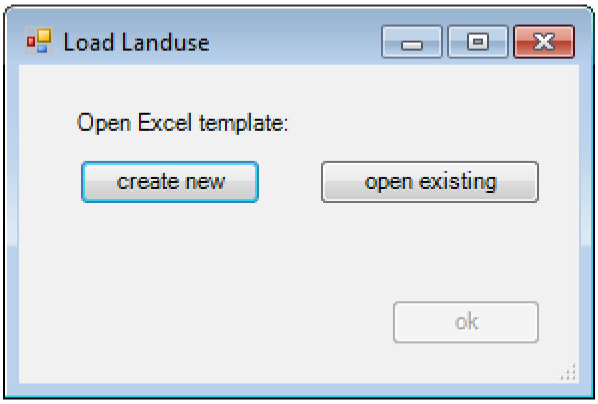
4.2.1 Entering land cover data in Excel (current default)

C-CALM is supplied with an empty template land use Excel Spreadsheet (landuse.xlsx) which is used by the model to input land cover data for each catchment. The first time C-CALM is run with a set of catchments, a new spreadsheet (ccalm_units_landuse.xlsx) is automatically created from the template. The ccalm_units_landuse.xlsx spreadsheet has columns for the numerical identifier (ModelUnitID) and area (m^2) for your SMUs which are automatically filled in by C-CALM. The land use scenario is created by users defining the proportion of the SMU into ccalm_units_landuse.xlsx (do not add any data directly into the template spreadsheet). Saving ccalm_units_landuse.xlsx enters the land covers for each SMU into the geodatabase.

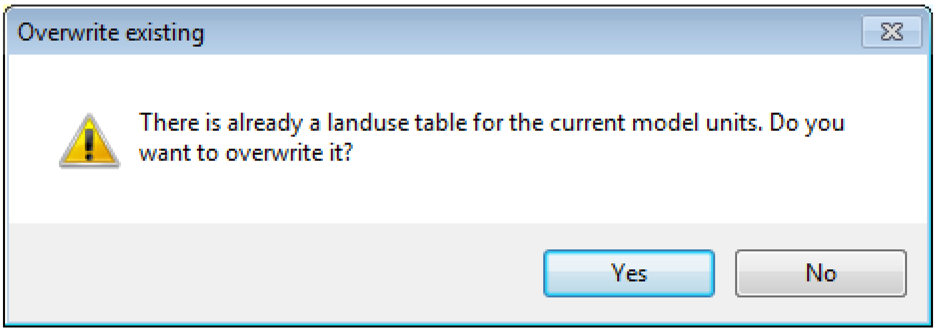
Having land use data stored in a spreadsheet makes it easy to create new land use scenarios by simply editing the proportions for each land cover.

Creating a new spreadsheet

1. Click the *create new* button in the *Load Landuse* window. This will automatically open a spreadsheet (ccalm_units_landuse.xlsx) created from the Excel spreadsheet template found in the C-CALM folder (*landuse.xlsx*).

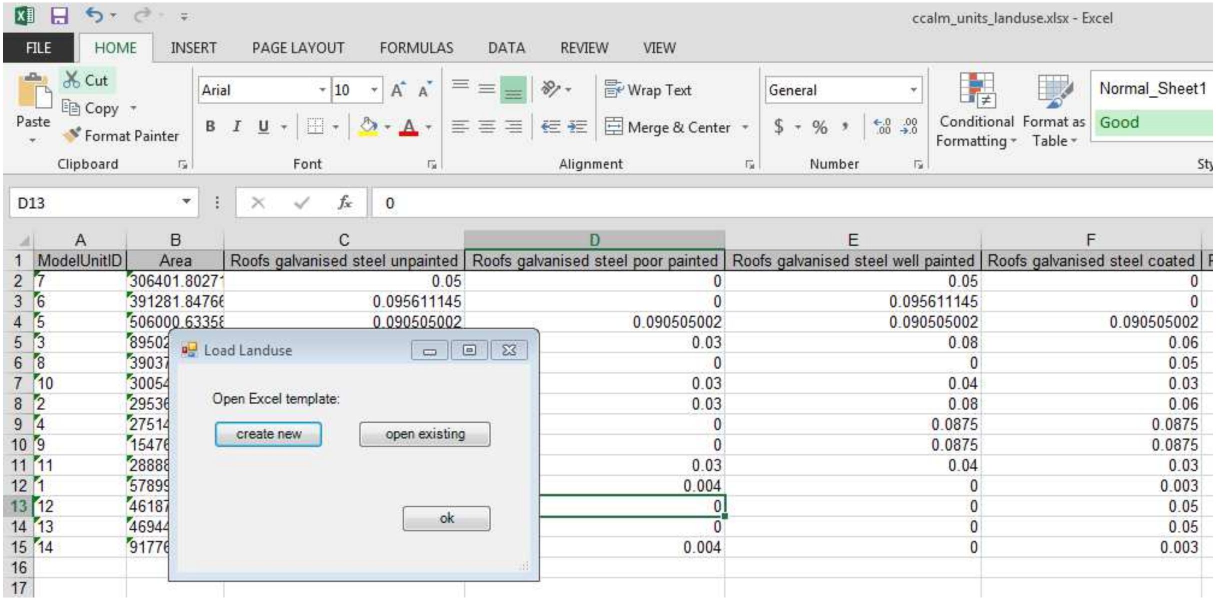


2. If there is already an existing ccalm_units_landuse.xlsx land use spreadsheet from an earlier modelling session, a window confirming that it should be overwritten will appear. Clicking *No* will open the existing spreadsheet for editing. Clicking *Yes* will open a new blank *ccalm_units_landuse.xlsx* spreadsheet.

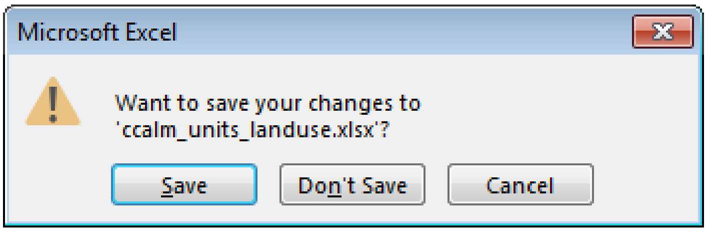


3. The ccalm_units_landuse.xlsx spreadsheet has land cover types (as listed in Table 2-1) as columns and SMUs as rows. Each catchment in the *c-calm_units* shape file has its own row with the catchment ID and total area (m^2) in the spreadsheet. Fill in the

fractional area (expressed as a number from 0 to 1 inclusive) of each land cover type for each SMU. Land use data can be copied in from other spreadsheets. Take care! The *ModelUnitID* (i.e., the numerical identifier entered in the previous section) may not be in numerical order. If a land cover is not present in an SMU, enter a zero value. **Do not leave cells blank.** The total proportional cover for each row must be equal to or less than one to calculate the correct loads.

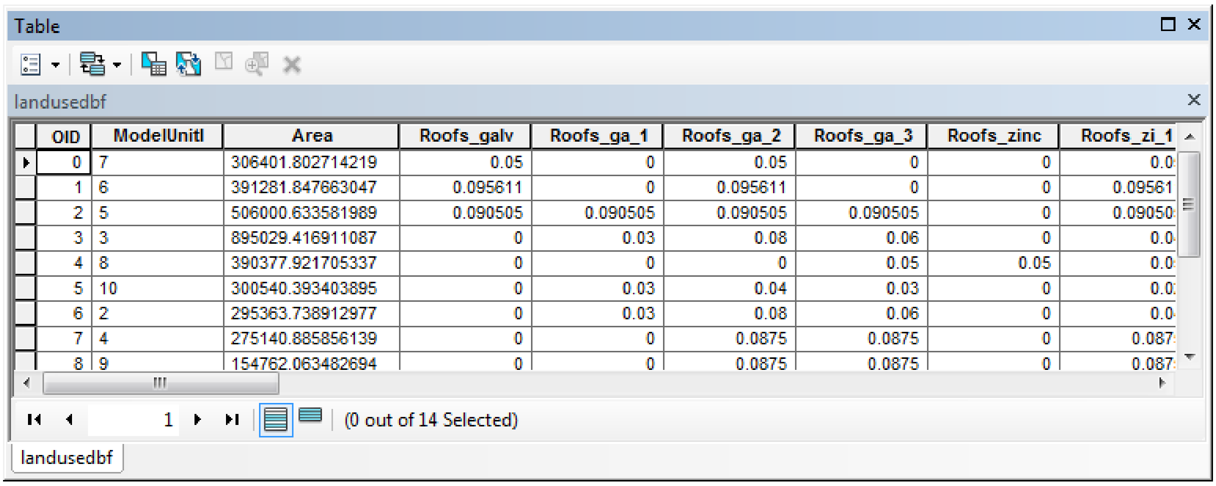


4. When the spreadsheet has been filled, click OK on the *Load Landuse* box to automatically close the spreadsheet. The save prompt will appear in Excel before the spreadsheet closes.



The spreadsheet must be saved at this step to enter the data into the geo-database (otherwise the database will not be undated).

5. The spreadsheet data will be added to the C-CALM geo-database. The data can be reviewed (but not edited) by displaying the *Source* tab in the *Table of Contents* (*TOC*), and opening the *landusedbf* attribute table.



Table

landusedbf

OID	ModelUnitI	Area	Roofs_galv	Roofs_ga_1	Roofs_ga_2	Roofs_ga_3	Roofs_zinc	Roofs_zi_1
0	7	306401.802714219	0.05	0	0.05	0	0	0.0
1	6	391281.847663047	0.095611	0	0.095611	0	0	0.09561
2	5	506000.633581989	0.090505	0.090505	0.090505	0.090505	0	0.09050
3	3	895029.416911087	0	0.03	0.08	0.06	0	0.0
4	8	390377.921705337	0	0	0	0.05	0.05	0.0
5	10	300540.393403895	0	0.03	0.04	0.03	0	0.0
6	2	295363.738912977	0	0.03	0.08	0.06	0	0.0
7	4	275140.885856139	0	0	0.0875	0.0875	0	0.087
8	9	154762.063482694	0	0	0.0875	0.0875	0	0.087

1 (0 out of 14 Selected)

landusedbf

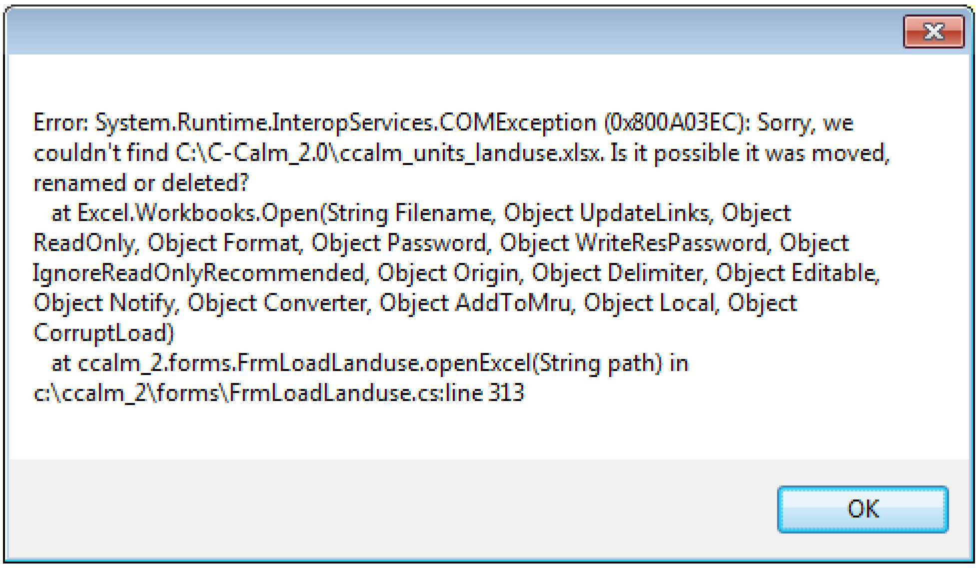
Loading an existing spreadsheet

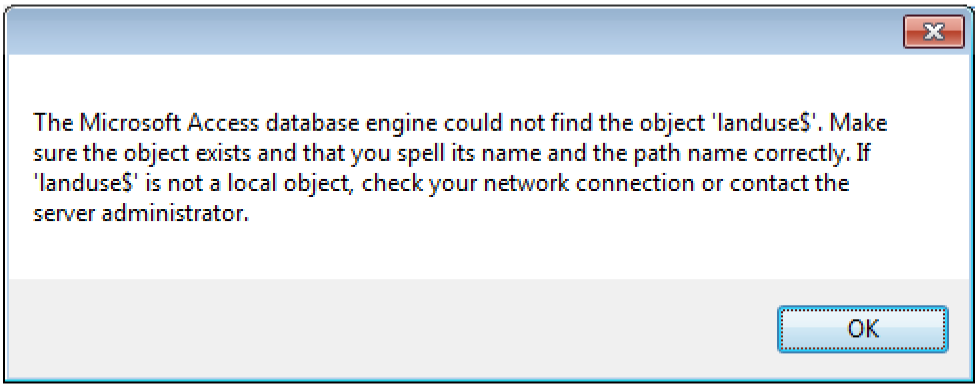
1. Click the *open existing* button in the *Load Landuse* window. This will automatically open the last saved *ccalm_units_landuse.xlsx* spreadsheet.

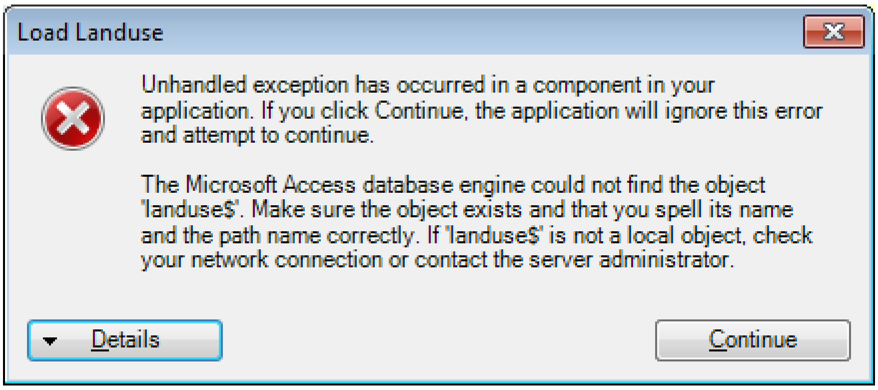
   The spreadsheet can be edited directly, however, it is recommended that land use scenarios be created in a separate master spreadsheet and copied into *ccalm_units*_landuse.xlsx using the *create new* option. Having a master spreadsheet will allow reference to land use scenarios at a later stage. For instance, the master could hold scenarios for pre-, during and post-development land use.

2. Click OK in the *Load Landuse* window. If changes have been made to the spreadsheet, Excel will prompt to save. The spreadsheet data will be added to the C-CALM spatial database.

TROUBLE SHOOTING: When I try to load an existing spreadsheet, I get these messages:





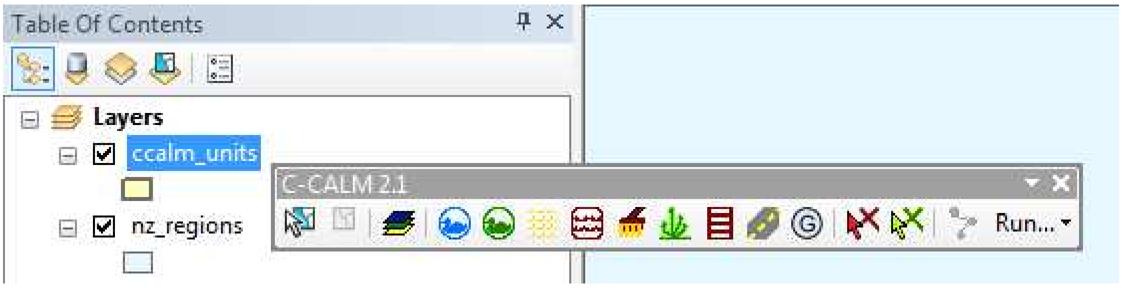


C-CALM cannot find the existing spreadsheet. This tool opens the most recently saved copy of *ccalm_units*_landuse.xlsx. When running C-CALM for the first time, chose the *create new* option to automatically create *ccalm_units_.xlsx* from the template *land_use.xlsx*. If you do have an existing land use spreadsheet, check that it is saved with the correct name and format in the C-CALM folder.

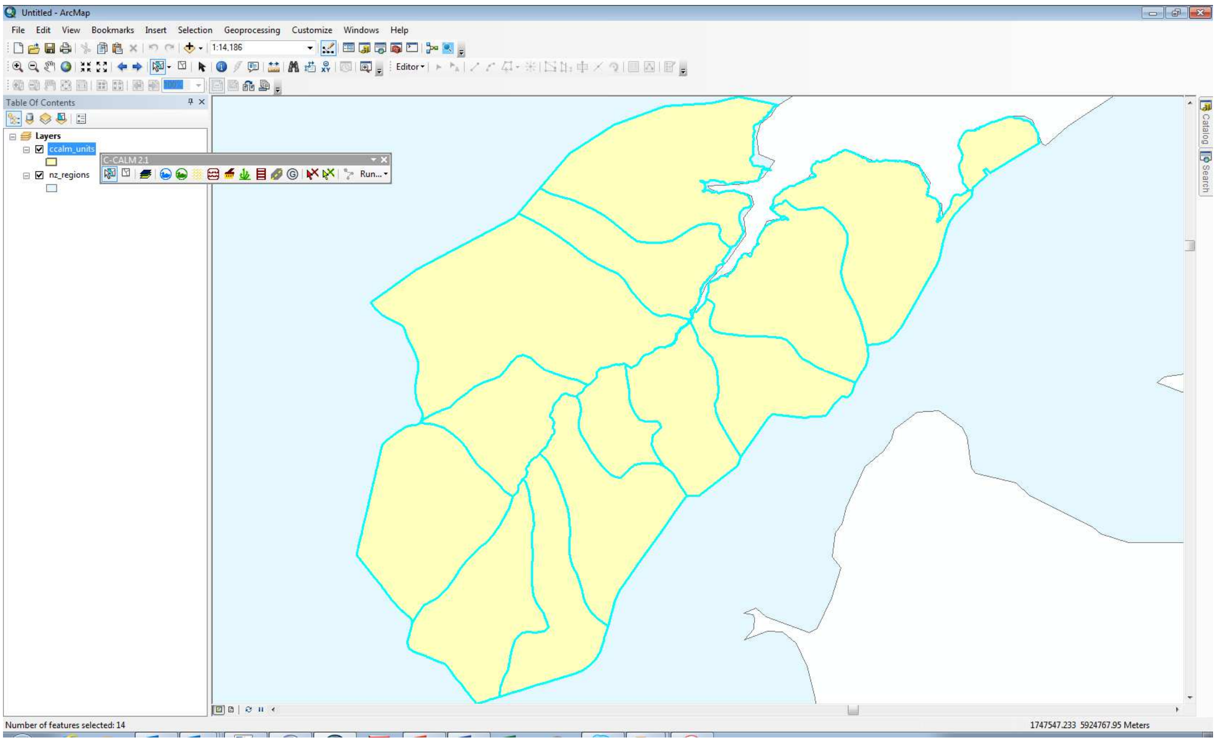
4.3 Running the model

C-CALM now has the information needed to simulate annual contaminant loads for the SMUs. It is a good idea to first simulate contaminant loads without treatment in order to provide a base level to assess the impacts of treatment on contaminant loads. Even if not simulating stormwater treatment, the following steps must be carried out:

1. Ensure that the *ccalm_units* shape file is highlighted in the *TOC*. This will display the treatment options available in C-CALM

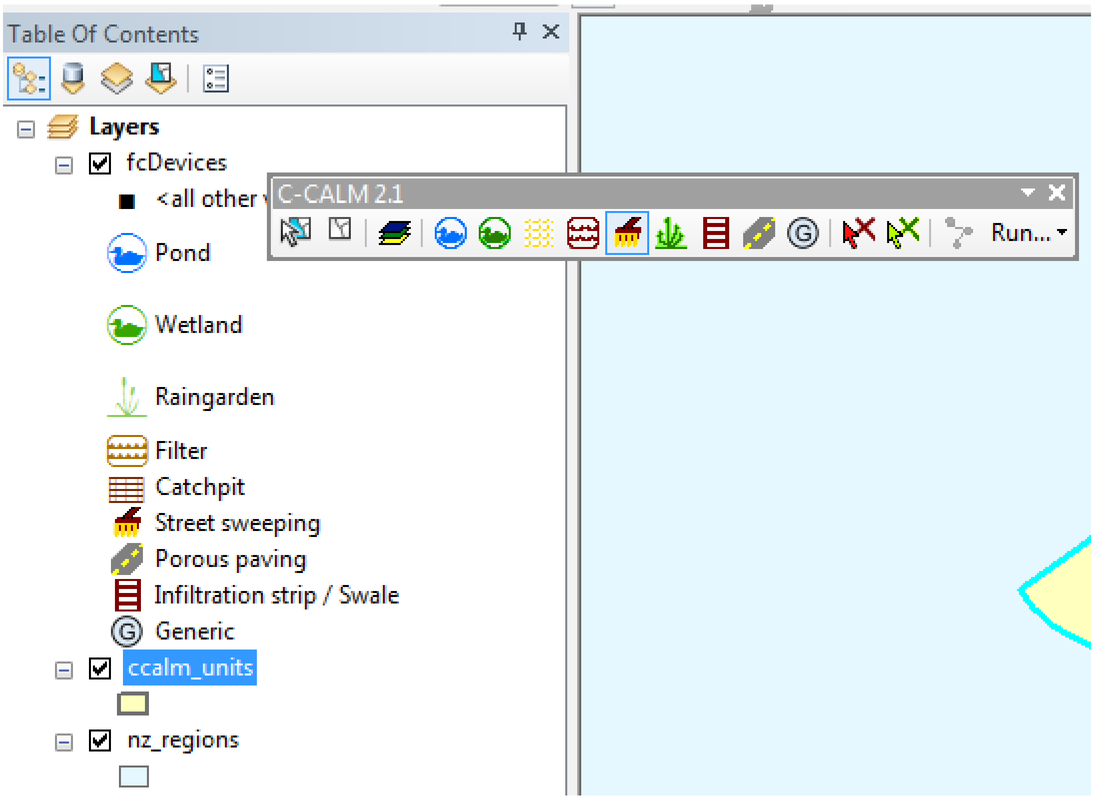


2. Click on the *select SMU* icon and click on the SMU(s) to be simulated. To make a multiple selection, hold down the *Shift* key during selection or click and drag over the area to be simulated. In this example, all the SMUs are to be simulated to provide a control contaminant load simulation for assessment of the treatment options. To remove a selection, click the *clear selection* icon on the toolbar.



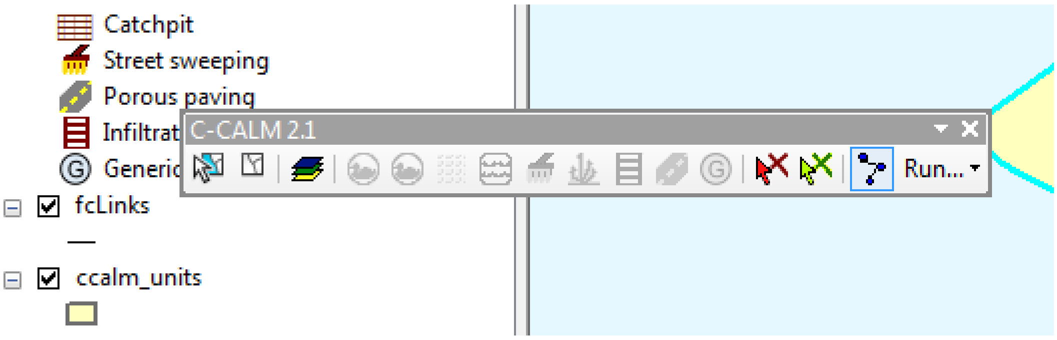
- Note:
  - Selected SMUs will be highlighted in blue as shown above.
  - Selections can also be made with the fcDevices shape file active.
  - The standard ArcMap selection tools can also be used.

3. Click on any of the treatment options to activate the *fcDevices* shape file which will be displayed automatically in the *TOC*. In the example, the *street sweeping* icon has been selected.

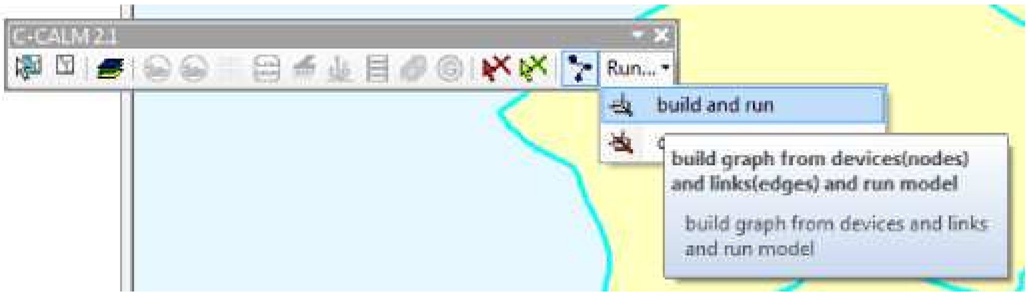


4. Click on the *fcDevices* shape file to activate the Model Run Tools on the interface toolbar.

5. Click on the *link* icon . This will activate the *fcLinks* shape file which will now be displayed in the *TOC*.

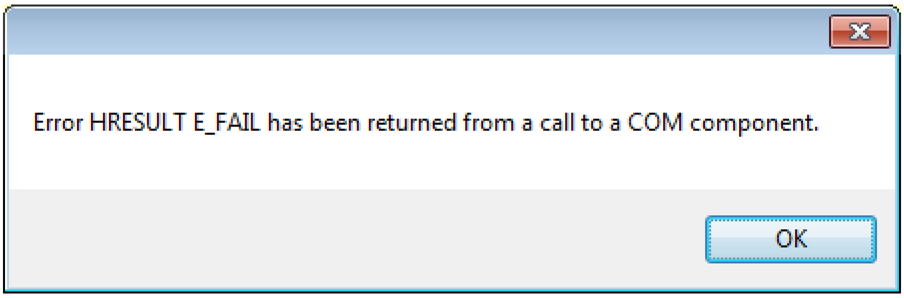


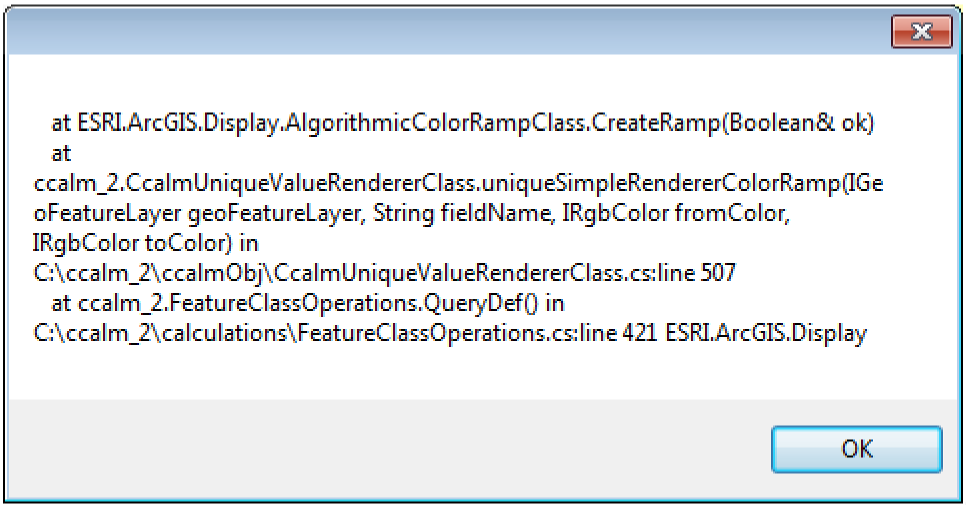
6. Click on the *Run* drop down menu and select *build and run*.



7. Wait for C-CALM to run. This may take several minutes. The more SMUs that are selected, the longer the run time. A progress bar will be displayed in the lower right-hand corner. Outputs are discussed in the next section.

TROUBLE SHOOTING – When I run C-CALM, I get the following messages and no results.





....

No SMU had been selected so that C-CALM was unable to run.

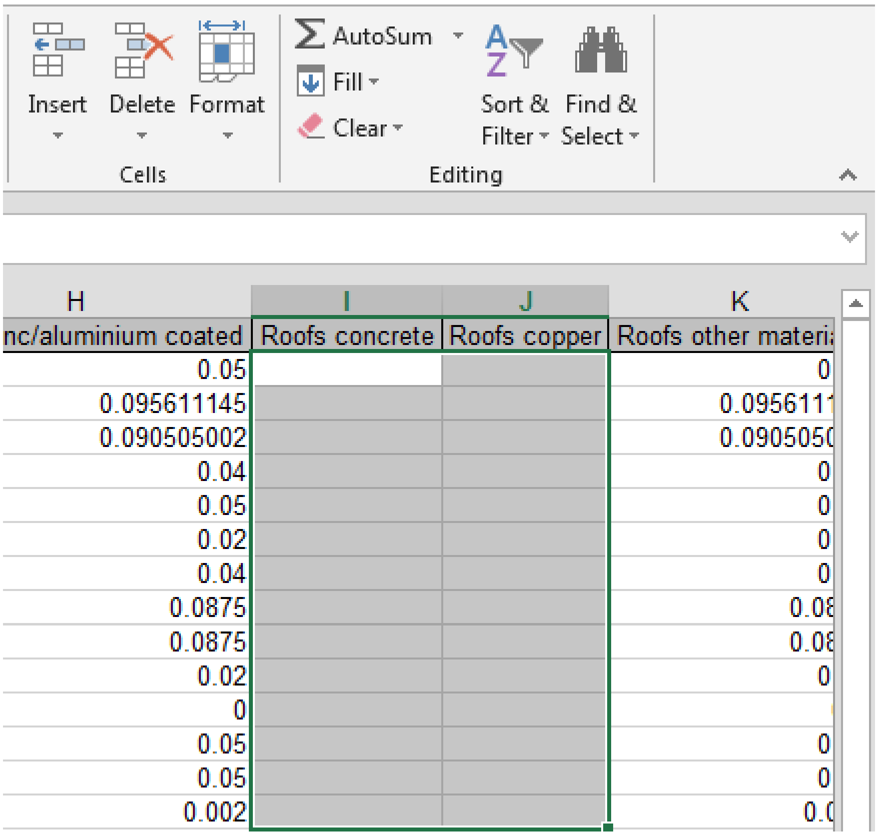
Close the *Outputs* table

Select the SMU(s) to be simulated.

Re-run C-CALM.

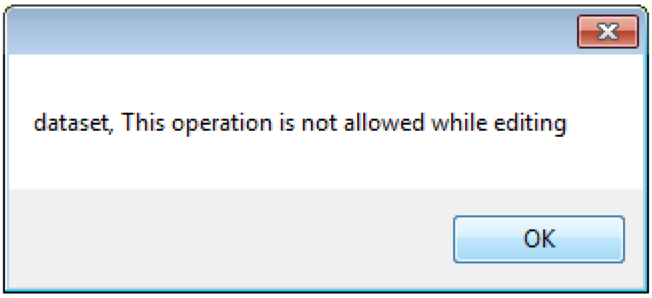
TROUBLE SHOOTING: I ran C-CALM and everything looked OK, but I got zero loads for some of my SMUs and others look like they are too low, why?

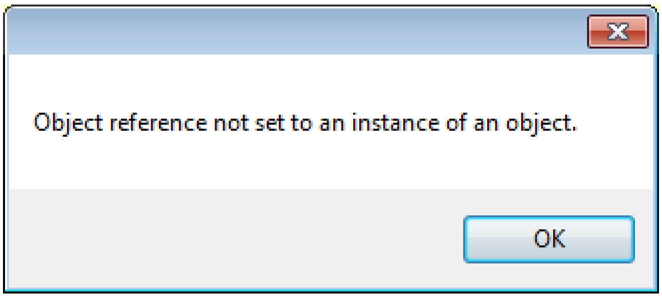
Check that you have zeros as place holders in the ccalm_units_landuse.xlsx spreadsheet for land covers which are not found in the simulated SMU. C-CALM will not recognise blank cells and will not update the database.



H	I	J	K
nc/aluminium coated	Roofs concrete	Roofs copper	Roofs other materi
0.05			0
0.095611145			0.0956111
0.090505002			0.0905050
0.04			0
0.05			0
0.02			0
0.04			0
0.0875			0.08
0.0875			0.08
0.02			0
0			
0.05			0
0.05			0
0.002			0.0

TROUBLE SHOOTING: Sometimes when I run C-CALM, I forget that the *link* icon is active and draw a link to nowhere. Then when I run C-CALM, the model stops running – usually when 30% complete. Sometimes I get this error





C-CALM requires the *link* icon to be clicked to activate the *fclinks* shape file before you can run the model. Note that once activated, the links icon does not have to be clicked again unless you are linking treatment options.

These error messages occur when you run C-CALM but are mid-way through drawing a link, for example if you have the link tool on and accidently click on the display. C-CALM will run but the Outputs table will be empty. You will need to restart ArcMap and C-CALM to continue (your treatment options will still be in place as they are stored in the database).

To avoid making this error, click on the ArcMap  Select Elements icon when you have created all the treatment options required before continuing your simulation.

To learn more about links, see Section 5.2.

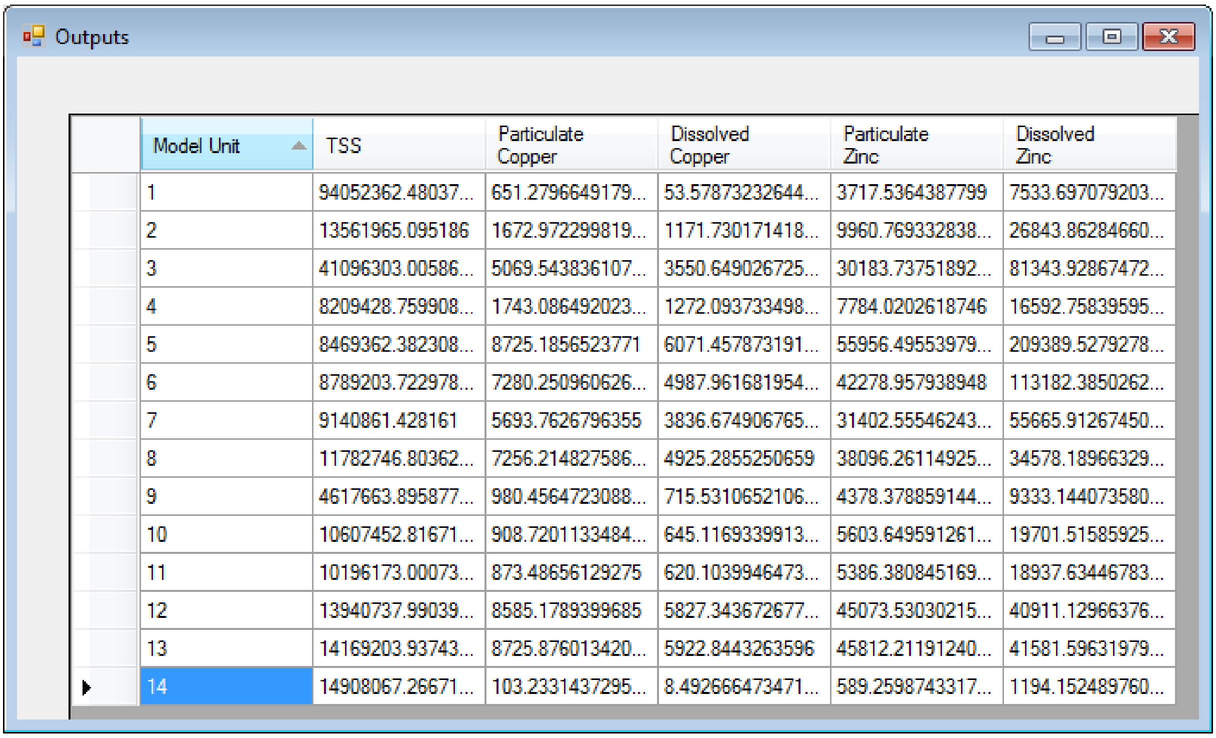
4.4 C-CALM results display

Once C-CALM has been run, results for each of the SMUs simulated will be provided in both tabular and map form. All results are given in grams per year (g/yr).

4.4.1 Outputs table

The outputs table provides the contaminant loads (g/yr) for TSS, particulate and dissolved copper and particulate and dissolved zinc for each of the simulated SMUs. The units simulated are identified in the first field (*ModelUnit*).

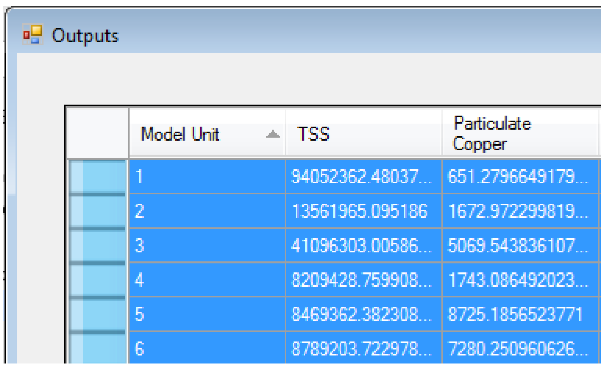
1. The results can be displayed in ascending or descending order for any field by clicking on the field name, here, SMUs are listed in ascending order.



Outputs

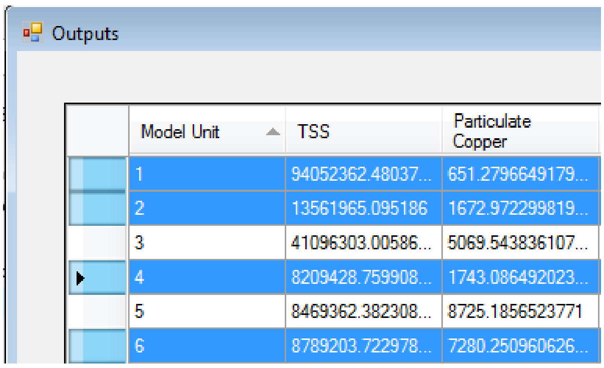
Model Unit	TSS	Particulate Copper	Dissolved Copper	Particulate Zinc	Dissolved Zinc
1	94052362.48037...	651.2796649179...	53.57873232644...	3717.5364387799	7533.697079203...
2	13561965.095186	1672.972299819...	1171.730171418...	9960.769332838...	26843.86284660...
3	41096303.00586...	5069.543836107...	3550.649026725...	30183.73751892...	81343.92867472...
4	8209428.759908...	1743.086492023...	1272.093733498...	7784.0202618746	16592.75839595...
5	8469362.382308...	8725.1856523771	6071.457873191...	55956.49553979...	209389.5279278...
6	8789203.722978...	7280.250960626...	4987.961681954...	42278.957938948	113182.3850262...
7	9140861.428161	5693.7626796355	3836.674906765...	31402.55546243...	55665.91267450...
8	11782746.80362...	7256.214827586...	4925.2855250659	38096.26114925...	34578.18966329...
9	4617663.895877...	980.4564723088...	715.5310652106...	4378.378859144...	9333.144073580...
10	10607452.81671...	908.7201133484...	645.1169339913...	5603.649591261...	19701.51585925...
11	10196173.00073...	873.48656129275	620.1039946473...	5386.380845169...	18937.63446783...
12	13940737.99039...	8585.1789399685	5827.343672677...	45073.53030215...	40911.12966376...
13	14169203.93743...	8725.876013420...	5922.8443263596	45812.21191240...	41581.59631979...
14	14908067.26671...	103.2331437295...	8.492666473471...	589.2598743317...	1194.152489760...

2. Clicking the top left grey-cell will select the entire table. All cells can also be selected by right clicking on the table to open the *copy options* box. To select a single row, left click on the grey-cell to the far left of the row. Multiple row selection can be made by holding down the *Shift* or *Ctrl* keys while clicking or by clicking and dragging.



Outputs

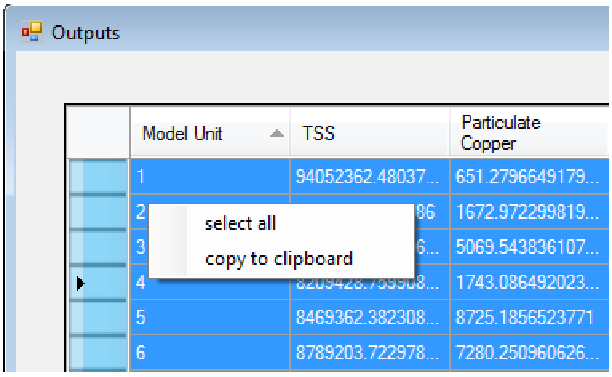
Model Unit	TSS	Particulate Copper
1	94052362.48037...	651.2796649179...
2	13561965.095186	1672.972299819...
3	41096303.00586...	5069.543836107...
4	8209428.759908...	1743.086492023...
5	8469362.382308...	8725.1856523771
6	8789203.722978...	7280.250960626...



Outputs

Model Unit	TSS	Particulate Copper
1	94052362.48037...	651.2796649179...
2	13561965.095186	1672.972299819...
3	41096303.00586...	5069.543836107...
4	8209428.759908...	1743.086492023...
5	8469362.382308...	8725.1856523771
6	8789203.722978...	7280.250960626...

3. Once a selection has been made, use either the keyboard shortcut *Ctrl + c*, or right click on the table to open the *copy options box* and select *copy to clipboard*.



4. The selected results can be pasted directly into other software packages for further display or analysis (see Table 4-1).

Table 4-1: Model results with no stormwater treatment.

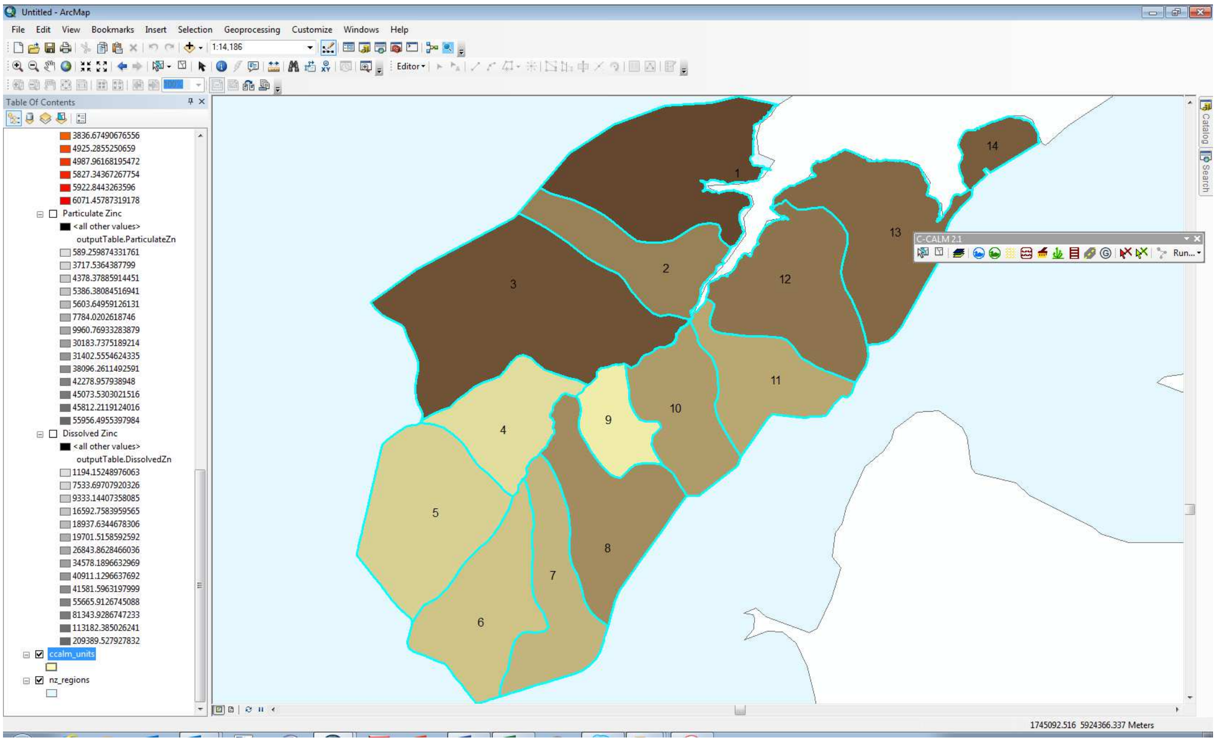
Model Unit	Model results (g/year)				
	TSS	Particulate Copper	Dissolved Copper	Particulate Zinc	Dissolved Zinc
1	94052362	651	54	3718	7534
2	13561965	1673	1172	9961	26844
3	41096303	5070	3551	30184	81344
4	8209429	1743	1272	7784	16593
5	8469362	8725	6071	55956	209390
6	8789204	7280	4988	42279	113182
7	9140861	5694	3837	31403	55666
8	11782747	7256	4925	38096	34578
9	4617664	980	716	4378	9333
10	10607453	909	645	5604	19702
11	10196173	873	620	5386	18938
12	13940738	8585	5827	45074	40911
13	14169204	8726	5923	45812	41582
14	14908067	103	8	589	1194

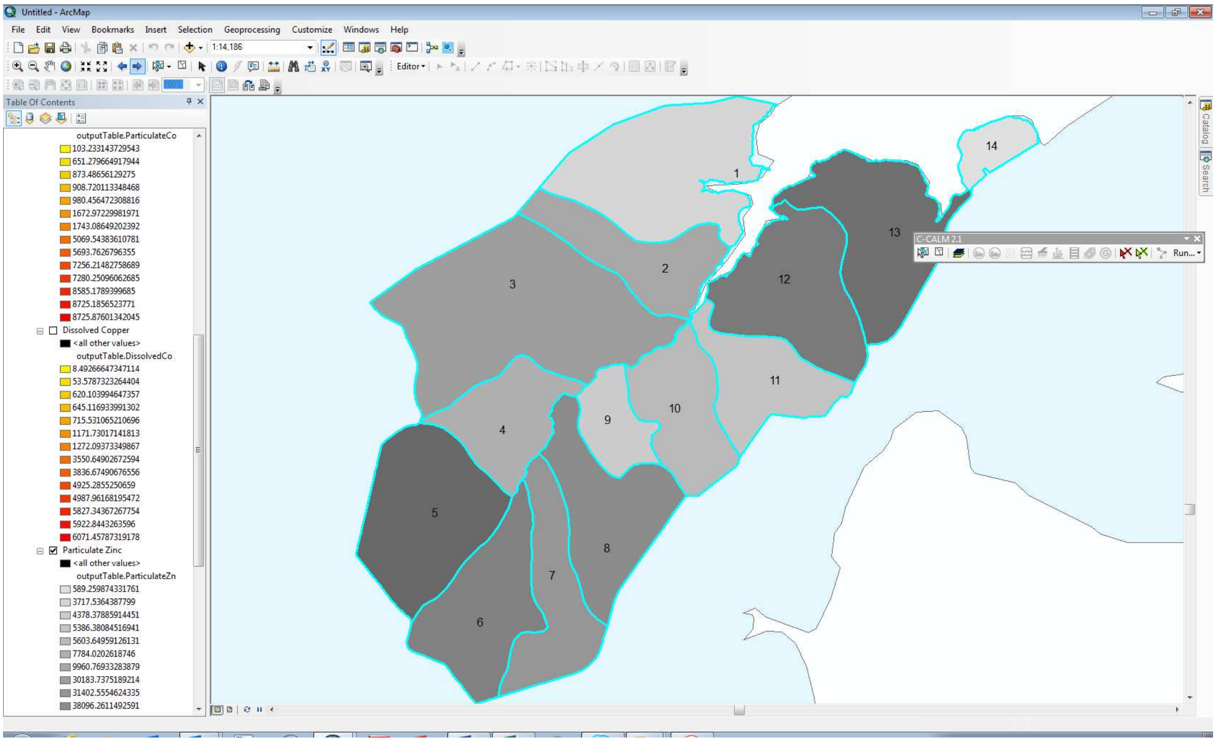
5. The output table can be closed, minimised or expanded by clicking the appropriate icon on the top right corner

If the table is accidently closed, the results are saved in the database and can be added as a standard attribute table to ArcMap. The *Source* tab must be selected on the *TOC* show the table location and to open it.

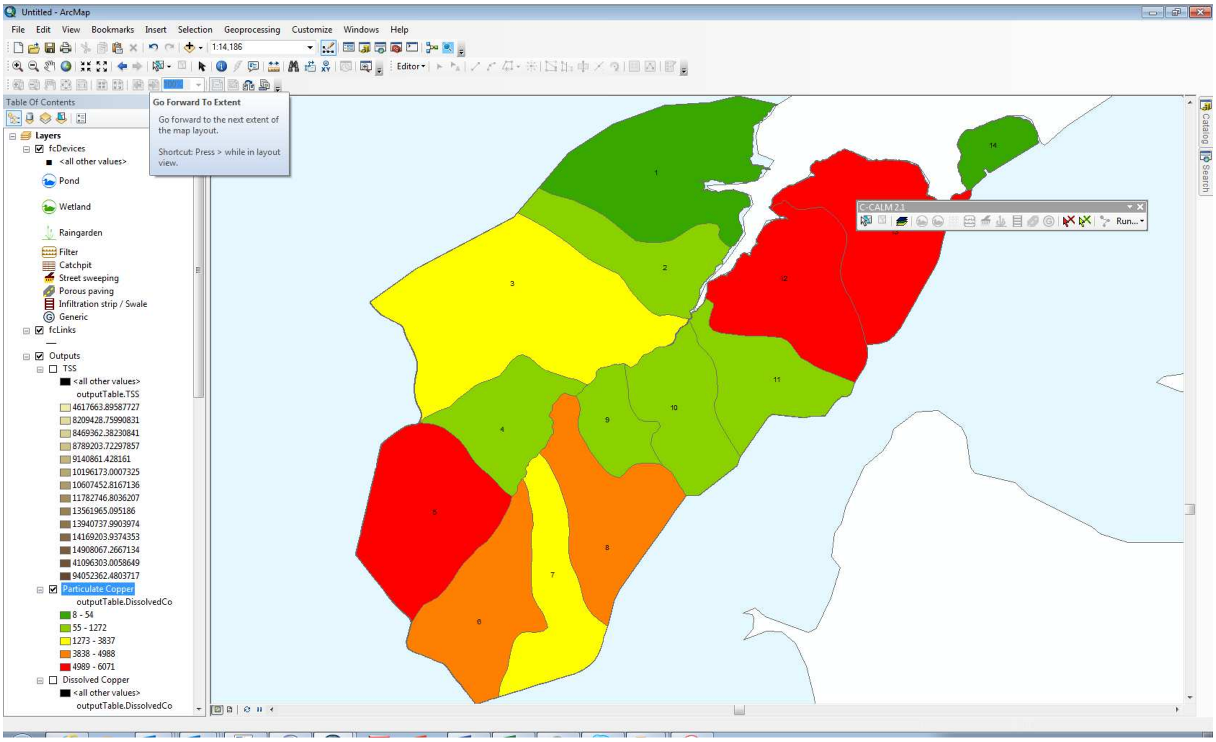
4.4.2 Maps

Mapped simulation results (g/yr) for each contaminant are held in the *Outputs group* layer, this holds multiple copies of the model output layer, one for each contaminant and each with its own symbology. The layers can be displayed like any other layer or shape file in ArcMap, by checking or un-checking their respective selection boxes in the *TOC*. The displays below are for TSS and particulate zinc. The selection highlight can be removed by deselecting the SMUs.





6. The default symbology is to show the contaminant load for each catchment (Categories; all values) using a standard ArcMap colour ramp (brown for TSS, yellow to red for copper and grey for zinc). Users can change the symbology for any contaminant as required. The example below uses the ArcMap Jenks distribution to map particulate copper with five classes and a green to red colour ramp.

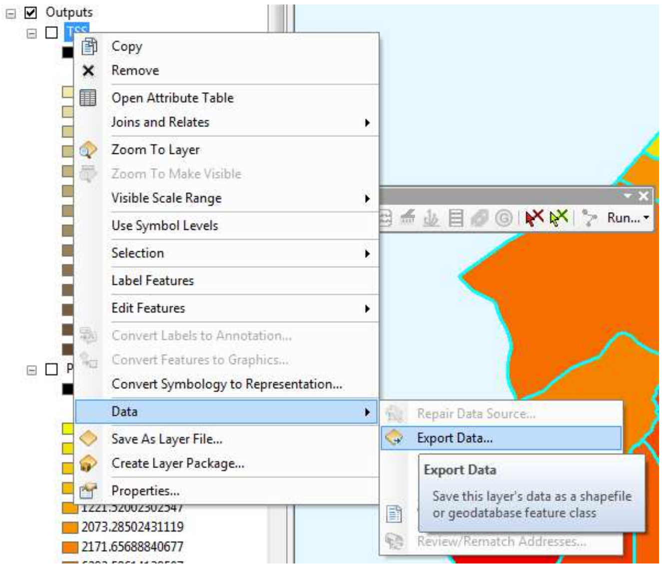


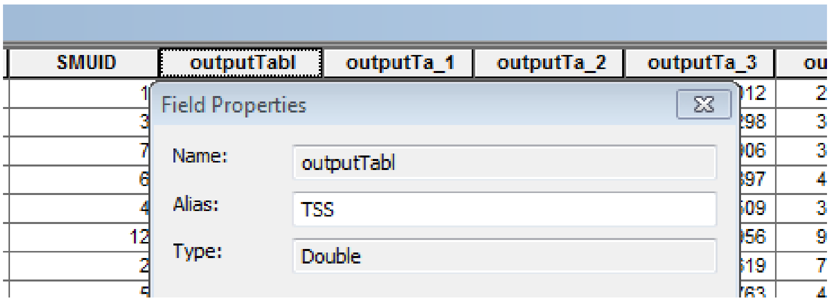
4.5 Saving settings and results

The model results and stormwater treatment options can be saved by:

1. Copying the results from the Output Table into another software package for further analysis or reporting (see Section 4.4.1).

2. Creating a shape file of the model results by exporting any of the Output group layers as a shape file (right click on any of the layers under the Outputs group layer and select *Export Data* under the Data menu). You will need to add an alias for each field as the resulting shape file will not preserve the field names from the output layer.





Note that like all layers in GIS, saving the Outputs layer as a new layer will result in the data being updated from the database following each new model run.

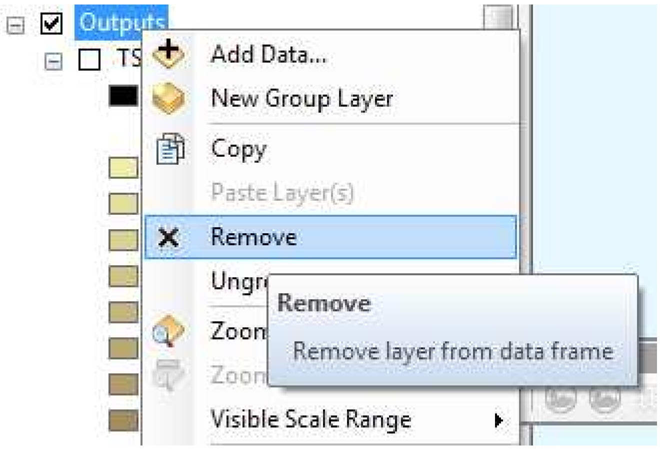
3. Saving the database under a new location for later reference. The C-CALM model set-up for treatment options is saved in the database. C-CALM draws on this database so that every new session will hold the treatment information from the previous session. However, any subsequent changes to the treatment set-up will be permanent in the database. To keep a copy of a set of treatment options, save a copy of the database into a new folder. To reuse the model set-up, replace the default database with the saved version.

4.6 Re-setting C-CALM for further runs

When using C-CALM to make multiple runs for different SMU selections, land use scenarios or stormwater treatment options, it is important to remove the previous results before re-running. C-CALM must not be re-run if the *Outputs* group of layers is present in the *TOC*.

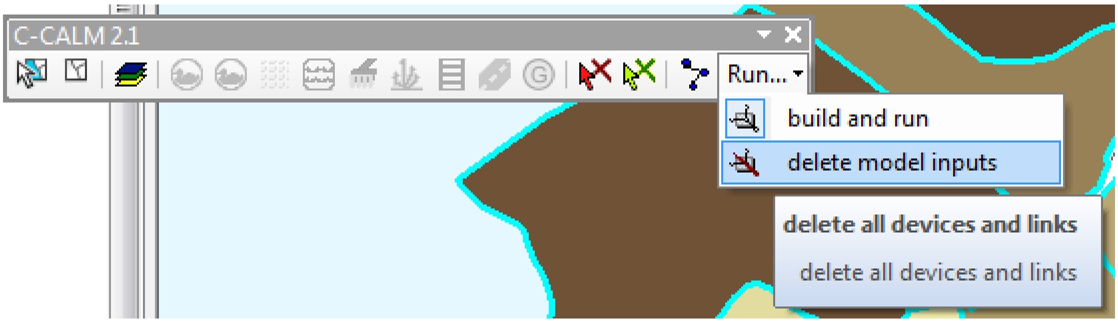
1. Ensure results and settings have been saved for future reference (see Section 4.5 above).

2. To remove the Outputs group layer but preserve treatment options, right click on the *Output group* layer in the *TOC* and select *Remove.*

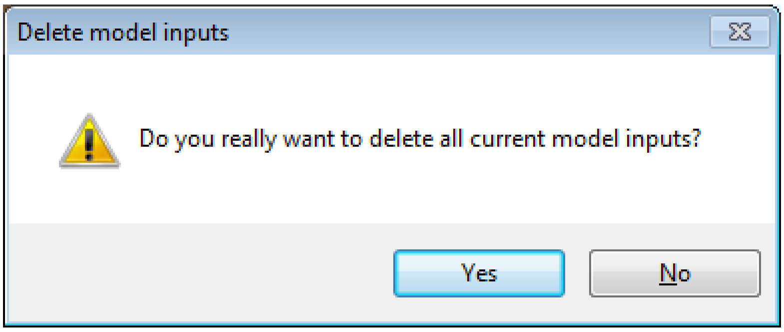


The treatment settings will remain in place for editing or the next C-CALM session as they are saved in C-CALM database

3. To remove the *Outputs group* layer and all treatment settings, click on the *Run* drop-down menu and select *delete model inputs.*



4. C-CALM will require confirmation that the model settings should be removed. Clicking *Yes* will reset C-CALM by removing model results from the display and treatment options from the database.


Delete model inputs
Do you really want to delete all current model inputs?
Yes
No

5 Simulating Stormwater Treatment

C-CALM is based on simple load calculations for each land cover which take into account the proportion of the land cover treated by each treatment option and the PSD of sediments entering that option. This means that C-CALM is capable of simulating contaminant removal (based on the performance rules discussed in Section 2.5) for combinations of options and land covers such as:

- A single treatment option treating runoff from a single land cover
- A single treatment option treating runoff from multiple land covers
- Multiple treatment options treating runoff from one or more land covers
- Multiple linked treatment options (trains) treating runoff from one or more land covers

The calculations are lumped within a SMU; this means that it is not necessary for the placement of a treatment option to reflect the true location of that option. Furthermore, C-CALM is not intended to model ALL of the options in a SMU, but rather the average removal that would be achieved using a representative device with similar design properties and source areas. For the modelled devices (ponds / wetlands and raingardens), the specific area of the device, rather than the actual area, is given on the understanding that device size changes with the size of the contributing area. That is, device performance is linked to its size relative size to the area which drains to it. The specific area of the device is defined as the area of the device (e.g., permanent pond surface area) as a fraction of the SMU impervious area.

Note that unless removed by the user (see Section 4.5), the treatment options held in the fcdevices shape file will be saved in the C-CALM database for the next C-CALM session – this means that C-CALM can be run with the same settings for successive sessions.

The following examples detail the steps needed to undertake the treatment scenarios outlined in Appendix B. The SMUs have been labelled in the maps using standard ArcMap display options (see the Labels tab in the Layer Properties box) for easy identification. The treatment scenarios have been developed to showcase C-CALM's ability to simulate different water treatment options in a range of configurations and do not represent real treatment options. It is possible to link all treatment options in all configurations, for this reason, NIWA relies on the best judgement of users to make suitable representations of water treatment.

5.1 Separate Treatment Options

In the following examples the treatment options are not linked in trains, so that the calculations for each option are independent.

5.1.1 Single treatment option (catchpits, no inserts), single source

In this example (Figure 5-1), runoff from major roads (5000-20000 v.p.d.) from SMU 4 (commercial land use, coarse PSD) is treated with catchpits (no filter inserts). PSD is coarse.

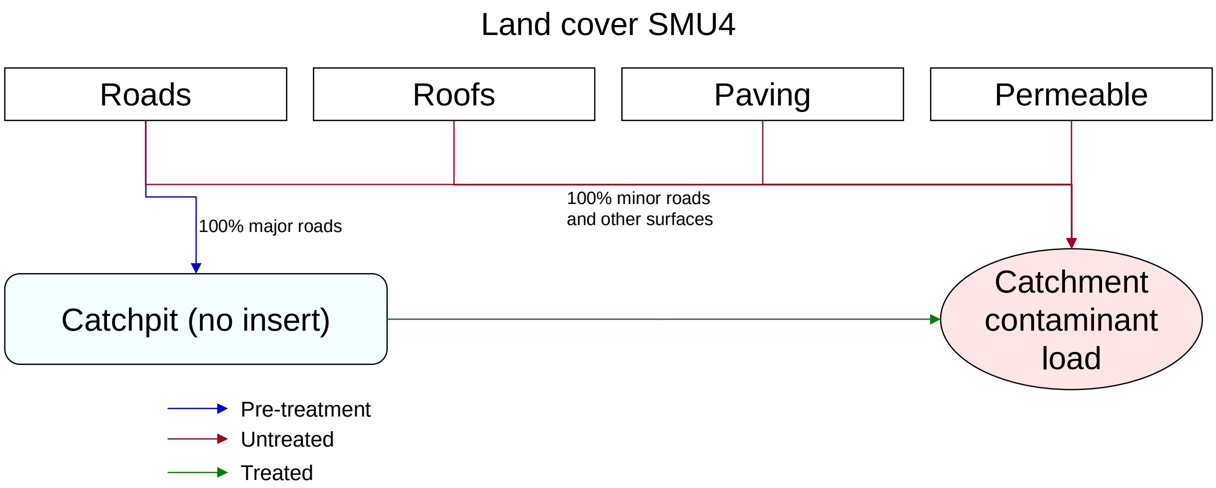
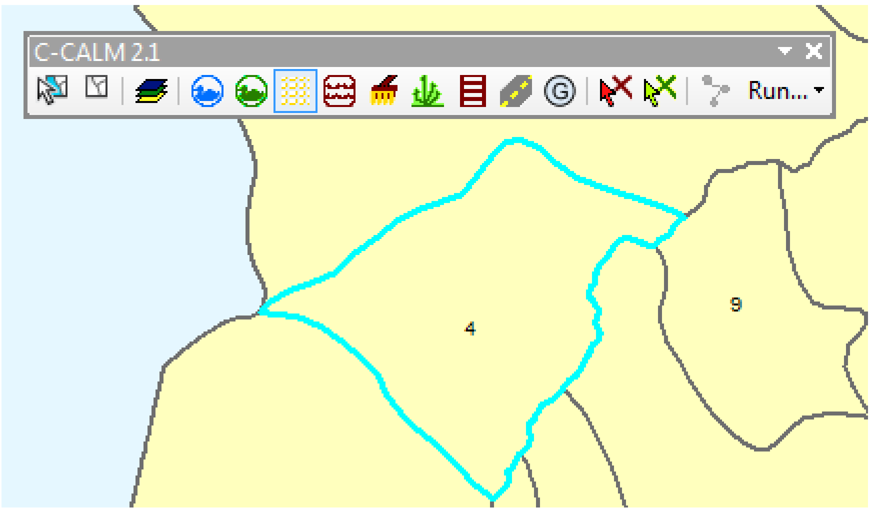


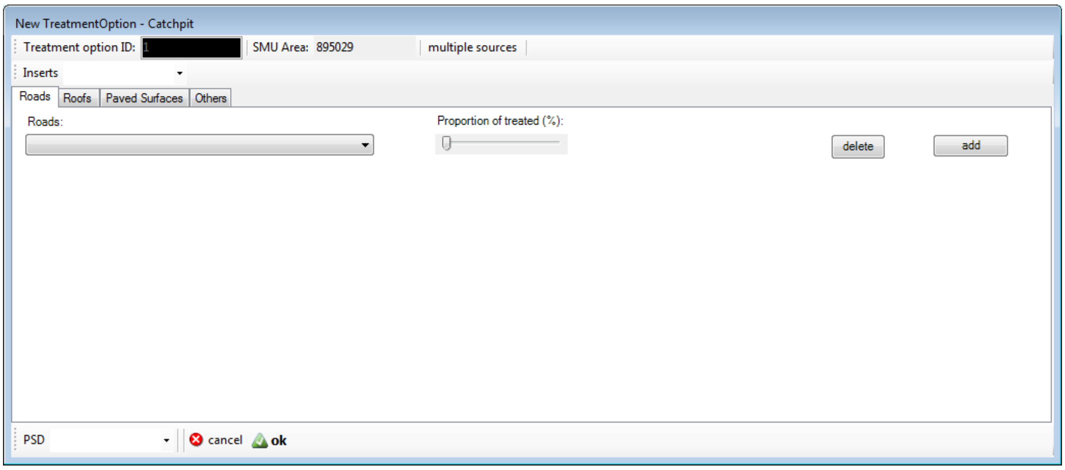
Figure 5-1: Stormwater treatment set-up for SMU 4.

1. Highlight the *ccalm_units* shape file in the *TOC* to activate the treatment options and select the SMU to be simulated.

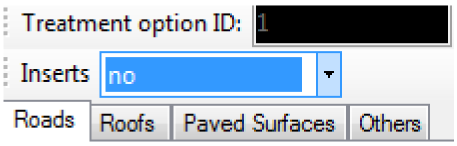
2. Click on the treatment option, in this case the *catchpit* icon.



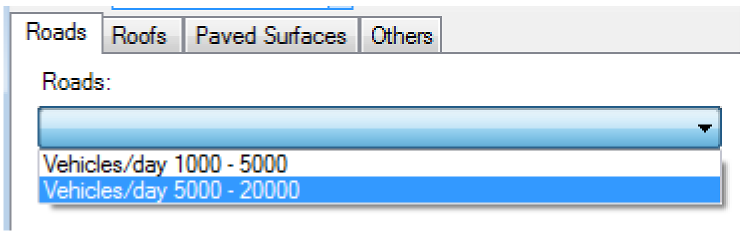
3. Click within the SMU boundary to open the *treatment set-up* window for the option.



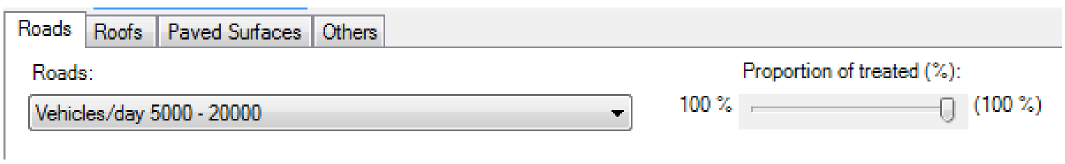
4. Under the *Inserts* drop-down menu, select whether catchpits are fitted with inserts (in this case, no).



5. Select the tab for the type of land cover (in this example roads) to be treated with the option. Note, catchpits are only available for roads and paved surfaces. Click on the drop down menu to see the land covers available for the selected cover type (as defined for the SMU in the Excel spreadsheet *ccalm_units*_landuse.xlsx) and select the option required for the simulation (here 5000 – 20000 v.p.d.). Note that an incorrect selection can be removed by clicking on the *delete* button. This allows a new selection to be made.

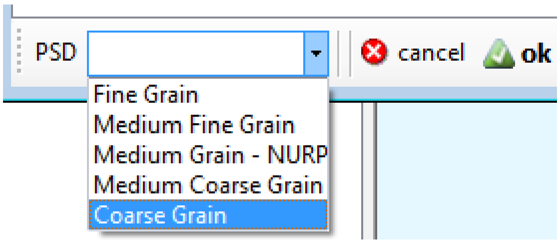


6. Use the slide counter to select the proportion of the cover type to be treated (clicking on the slide will move the pointer in 5% intervals). The percentage on the left hand side of the slider shows the proportion treated by the current option. The percentage on the right had side of the slider (in parenthesis) shows the total proportion treated by all treatment options in the SMU. For full treatment, set the proportion of roads to be treated to 100%.

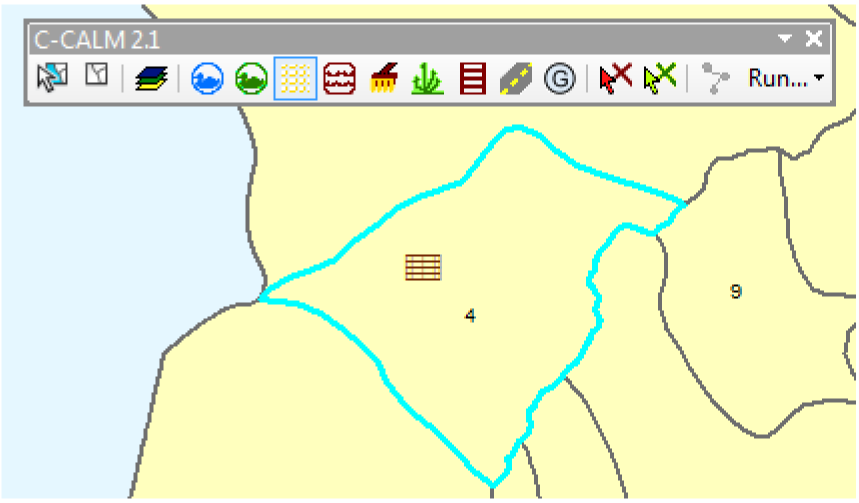


The percentage on the left hand side of the slider shows the proportion treated by the current option. The percentage on the right had side of the slider, in parenthesis, shows the total proportion treated by all treatment options in the SMU (i.e., if there are more than one treatment option).

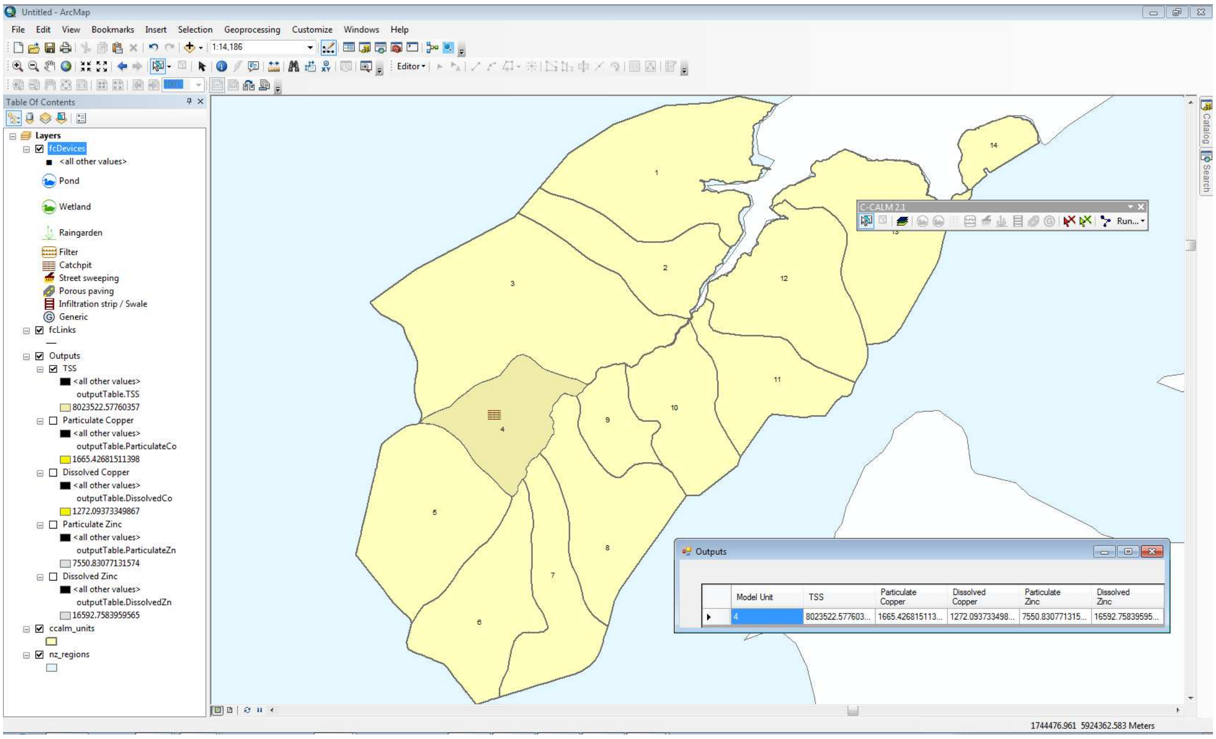
7. Choose the PSD of sediments reaching the treatment option. Note, most treatment types will require a removal rating choice (high, medium or low) for dissolved metals – these options are not available for catchpits and street sweeping which assume that dissolved metals are not treated. For this example, a coarse grain PSD has been chosen.



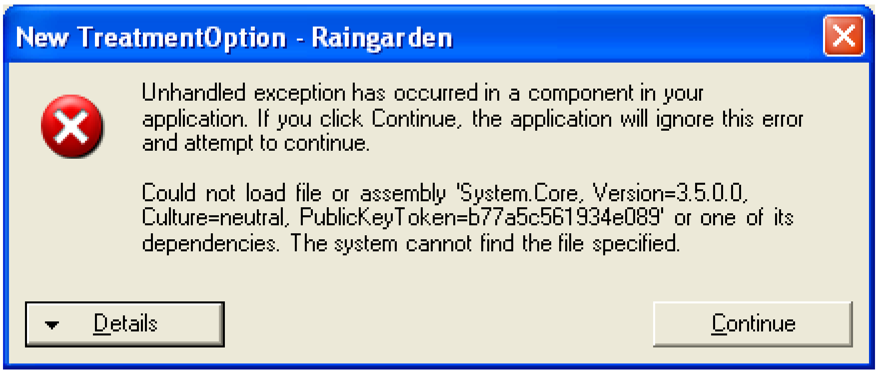
8. Click OK. A catchpit symbol will appear in the SMU.



9. Run C-CALM according to the instructions above (Section 4.3). C-CALM will display the treated load for the SMU.



TROUBLESHOOTING: When I click OK after inserting a treatment option, I get a message like this and my treatment option does not appear in the SMU.

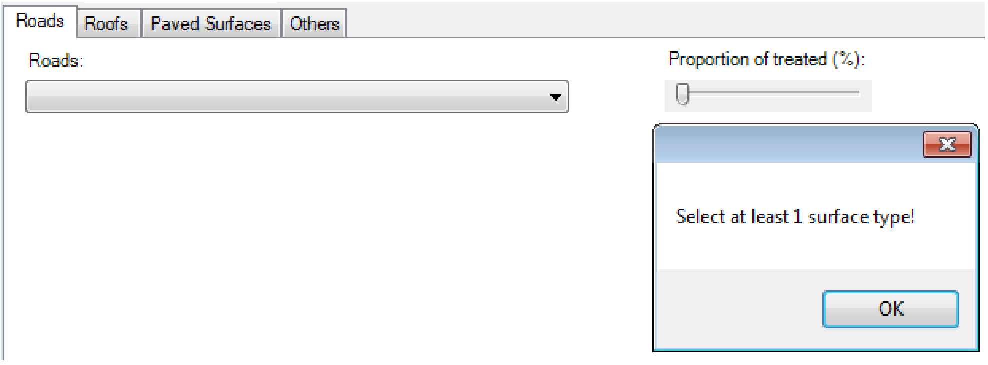


C-CALM requires .NET Framework 4.0 or later to be installed. (The error message above was generated for an earlier version of C-CALM compiled under .Net Framework 3.5)

TROUBLE SHOOTING: What happens if I forget to fill a box in the treatment option set-up or if I forget to set the proportion of land cover treated?

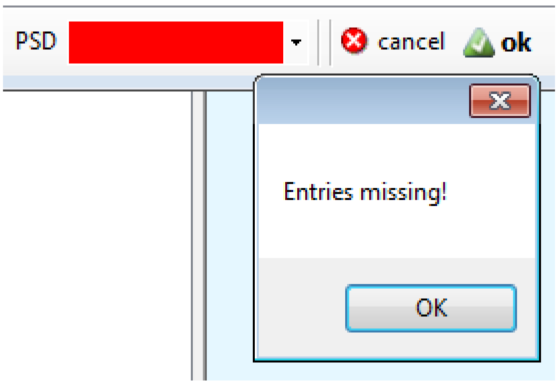
C-CALM will not allow you to click OK to insert a treatment option if information is missing from the treatment set-up.

No land cover selected for treatment:



Missing land cover proportion:

Missing treatment setting (here PSD):



5.1.2 Single treatment option (detention pond), multiple sources with split proportions

In this example (Figure 5-2), stormwater generated by the half the impervious surfaces found in SMU 6, an old industrial area with medium coarse PSD is treated by an end-of-line stormwater pond.

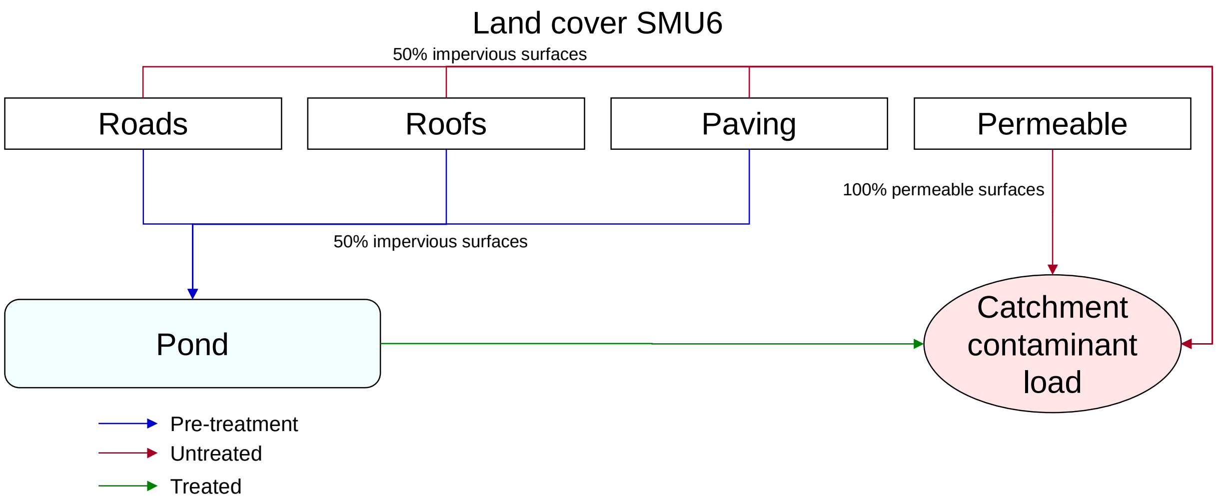


Figure 5-2: Stormwater treatment set-up for SMU 6.

The pond has the following parameters (with reference to the catchment properties in Appendix Four):

- Catchment type – industrial
- Imperviousness – 90 % (representing 86% imperviousness see Appendix Four) Slope to gutter – 0.03
- Specific area – 1.5% or 150 m^2/ha (i.e., a pond area of around 2500 m^2 serving 16.8 ha of impervious surfaces)
- Hydraulic Efficiency – 3.5 (good, see Appendix D)
- Depth/invert level – 1.5 m
- Weir width – 3 m (e.g., a standpipe of 1 m diameter)
- Extended detention – yes

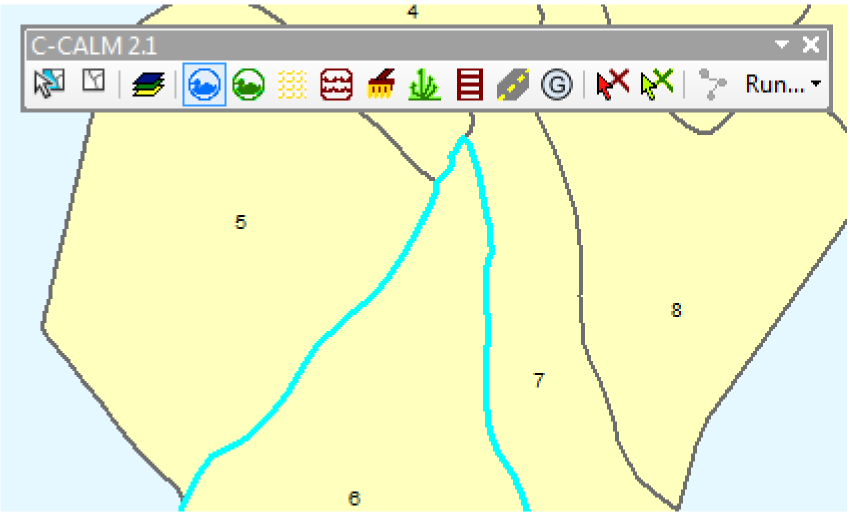
This combination gives the following treatment efficiency (%) in the C-CALM database for each particle size class in the PSD:

Band1	Band2	Band3	Band4	Band5	Band6	Band7	Band8	Band9
38	40	48	71	94	99	99	99	99

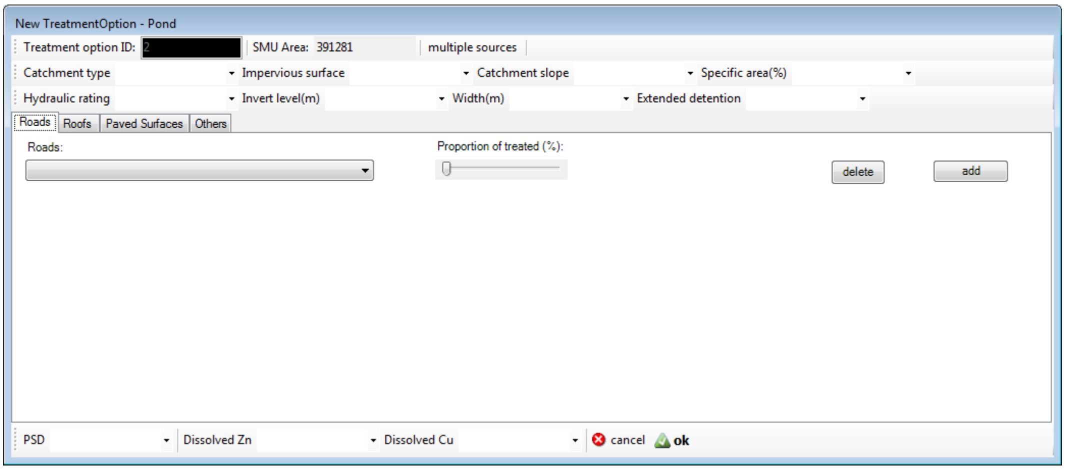
The removal efficiency for dissolved metals is medium.

1. Close the output table and remove the output layers from the previous run. Highlight the *ccalm_units* shape file in the *TOC* to activate the treatment options and select the SMU to be simulated.

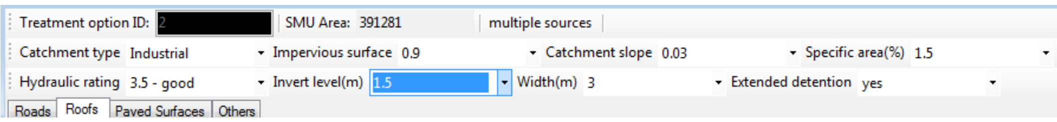
2. Click on the *treatment option* icon, here ponds.



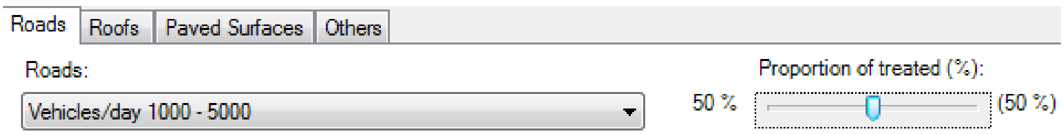
3. Click within the SMU boundary to open the *treatment set-up* window for the option.



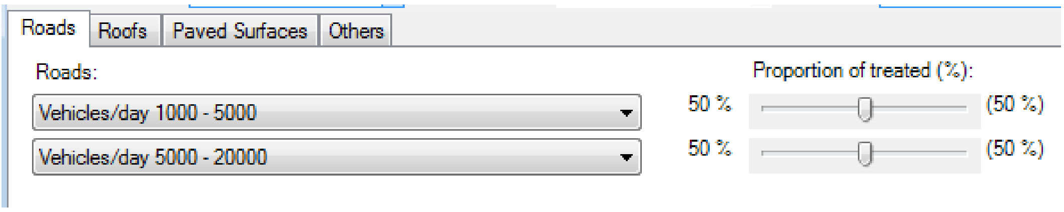
4. Fill in the pond parameters which best approximate the pond design specifications for the SMU.



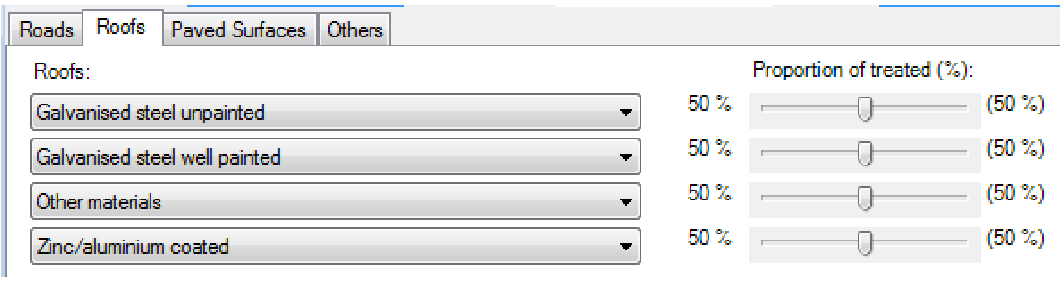
5. Select the tab for the first category of land cover to be treated with the option (here roads). Click on the drop down menu to see the land covers available for the selected cover type (as defined for the SMU in the Excel table *ccalm_units*_landuse.xlsx). Select the first land cover type (here 1000 – 5000 v.p.d.). Use the slide counter to select the proportion of the cover type to be treated. In this example runoff from half of the impervious surfaces drains to the pond, so the slide is moved to 50%.

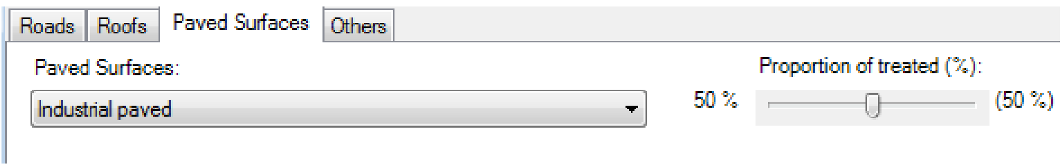


6. Click the *add* button to select the next land cover to be treated (here 5000 – 20000v.p.d.). To remove a land cover that has already been entered, click the delete button that is associated with that land cover. Use the slide counter to select the proportion of the cover type to be treated (50% in this example).

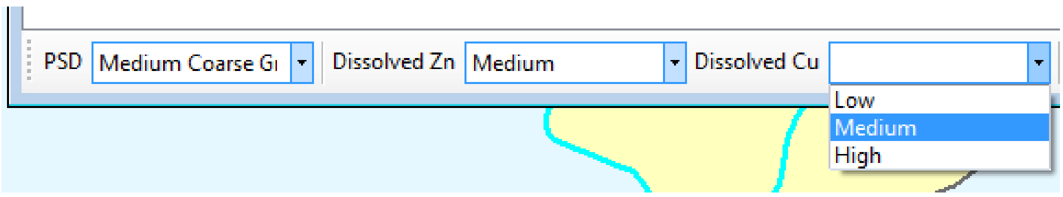


7. Continue through the remaining cover type tabs in the same manner, until all of the land covers to be treated have been entered (here, half of all impervious surfaces).



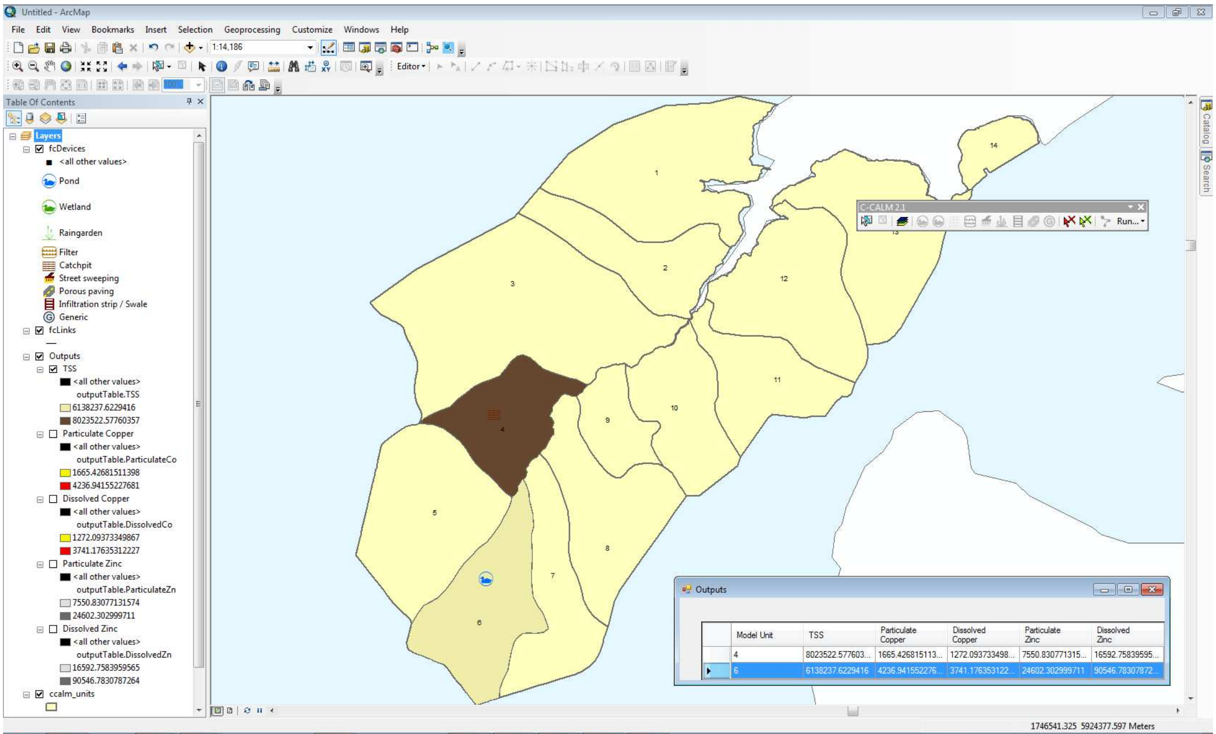


8. Select the PSD and level of removal efficiency for the dissolved metals and particulates where required (in this example, medium coarse PSD and medium removal of dissolved metals).

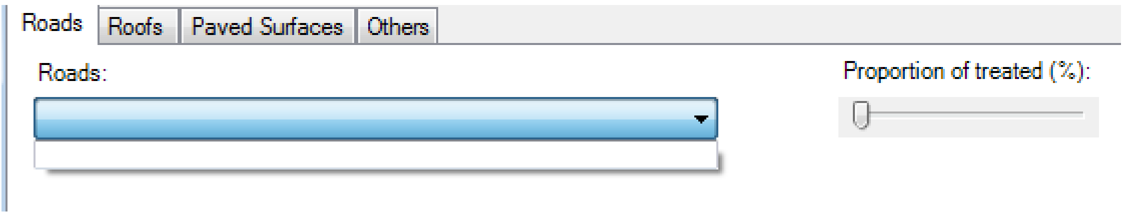


9. Click OK, the symbol for the treatment option will appear in the SMU.

10. Run C-CALM



TROUBLE SHOOTING: The land cover I want to treat is not available under the drop down menu.



This means that either the land cover is not present in the land use table (i.e., *cccalm_units_landuse.xlsx*) for the SMU or is 100% treated by earlier treatment options. .

5.1.3 Multiple unlinked treatment options (generic, porous paving and swales); single source with proportion split

In this example (Figure 5-3), SMU 10 (low intensity residential, medium coarse PSD) has a traditional reticulated stormwater system draining roads (1000-5000 v.p.d) that has been retrofitted with a generic treatment option[5] (25% of road runoff, 75% TSS removal and 30% each of dissolved zinc and copper removal), porous paving (25% of roads are porous with medium TSS removal and low dissolved metal removal) and swales (50% of road runoff with high removal of TSS and medium removal of dissolved metals.). This treatment scenario requires three options to be set-up in C-CALM.

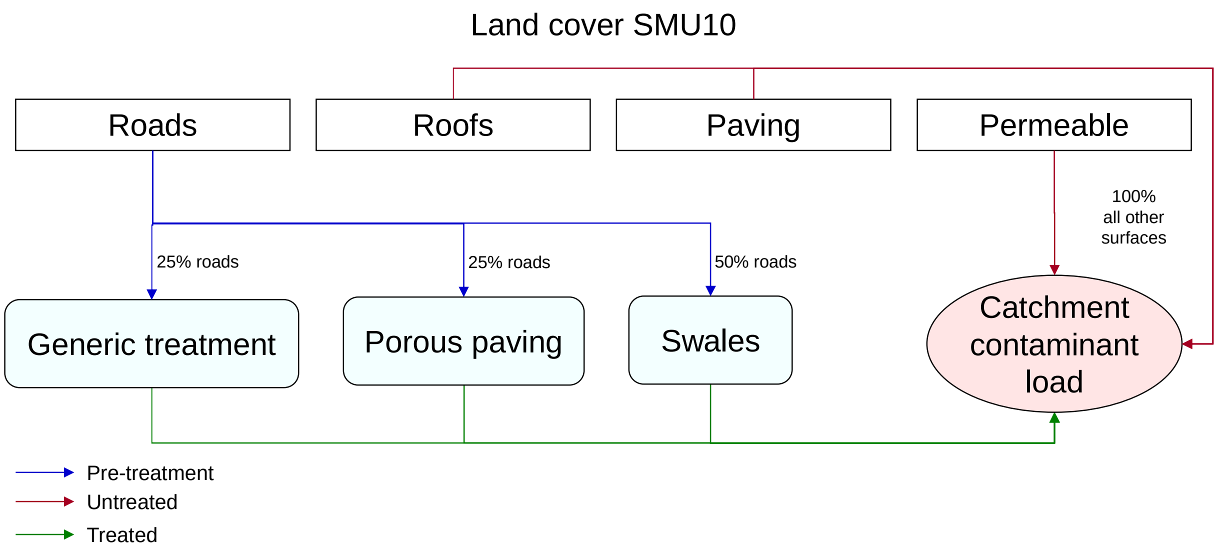
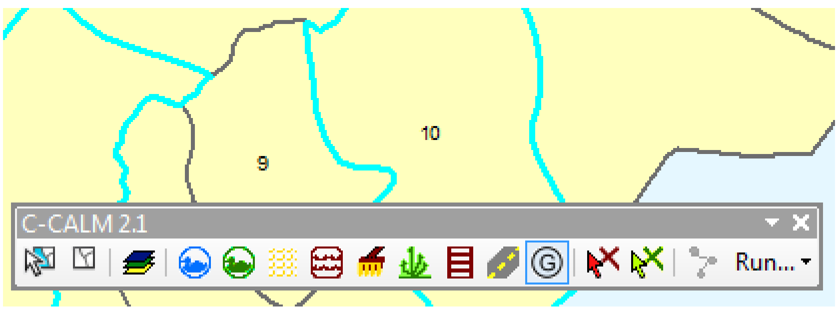


Figure 5-3: Stormwater treatment set-up for SMU 10.

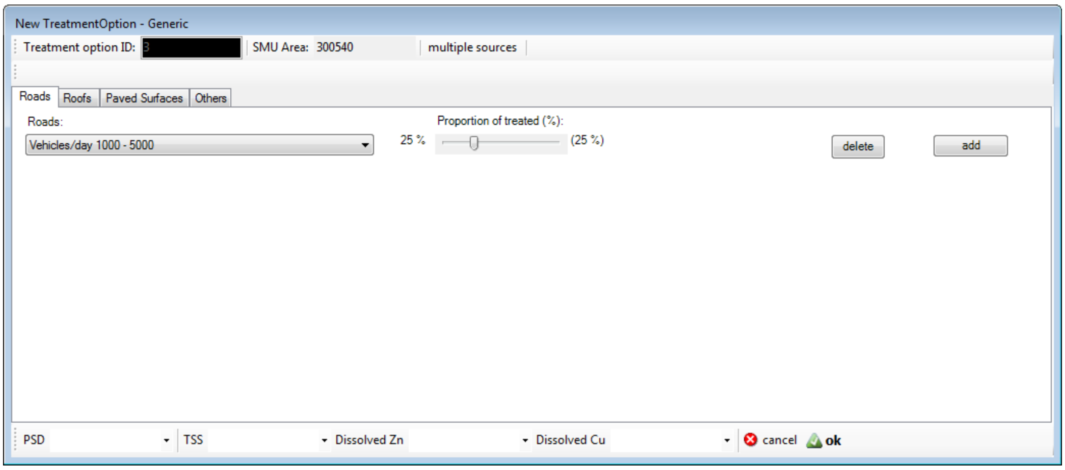
1. Close the output table and remove the output layers from the previous run. Highlight the *ccalm_units* shape file in the *TOC* to activate the treatment options and select the SMU to be simulated.

2. Click on the first treatment option to be added, in this example, the *Generic treatment* icon

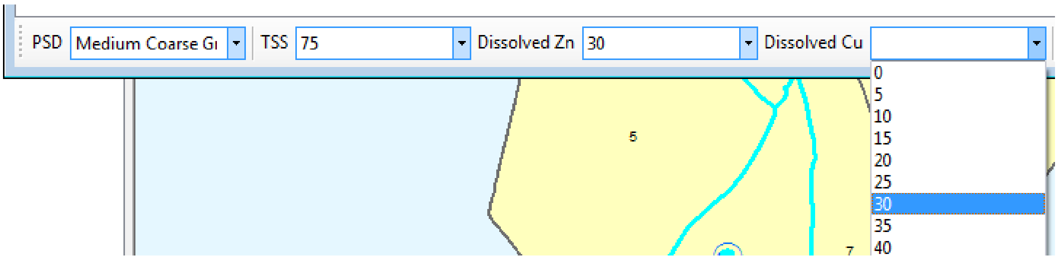


3. Click within the SMU boundary to open the *treatment set-up* window for the option. Fill land use as required (25% of road runoff).

[5] That is, the treatment option has a user specified removal efficiency.

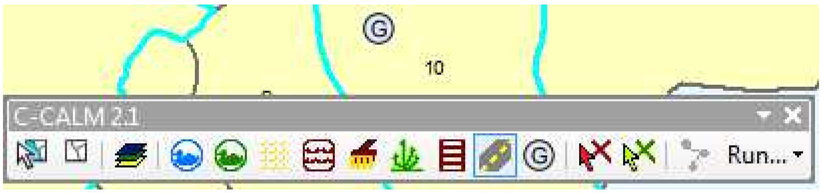


4. The generic treatment option requires users to select the removal efficiency for each contaminant (here 75% TSS removal and 30% each of dissolved zinc and copper)

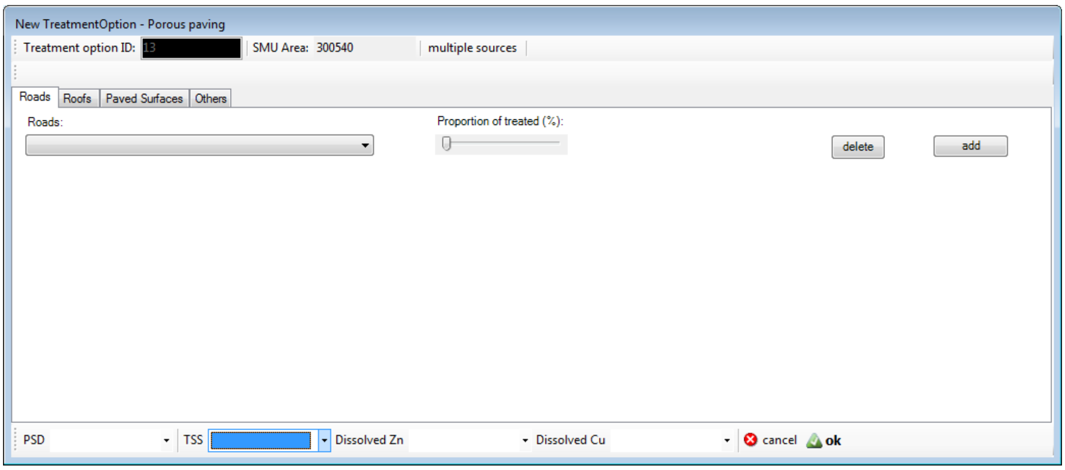


5. Click OK, the symbol for the treatment option will appear in the SMU.

6. Click on the second treatment option to be added, in this example, the *porous paving* icon

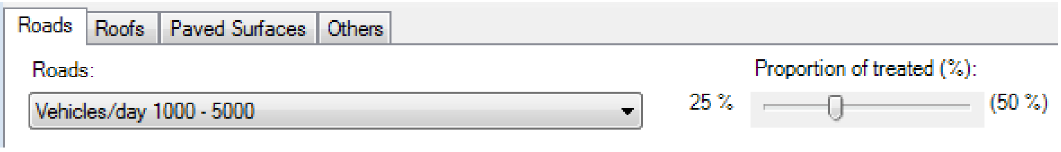


7. Click within the SMU boundary to open the *treatment set-up* window for the option.

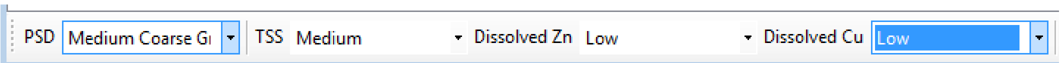


8. Click on the tab for the land cover type and select the land cover to be treated from the drop down menu. Porous paving is only available for roads and paved surfaces.

9. Move the slider to the proportion of the land cover treated. The slider will show the percentage of the land cover treated by the second option on the left (in this example, 25%) and the total proportion treated by all the treatment options on the right in parenthesis (in this case 25% by the generic treatment option and 25% by porous paving giving a total of 50% treatment). If the level of treatment reaches 100% of a land cover, this land cover will no longer be available in the drop down menu for subsequent treatment options.



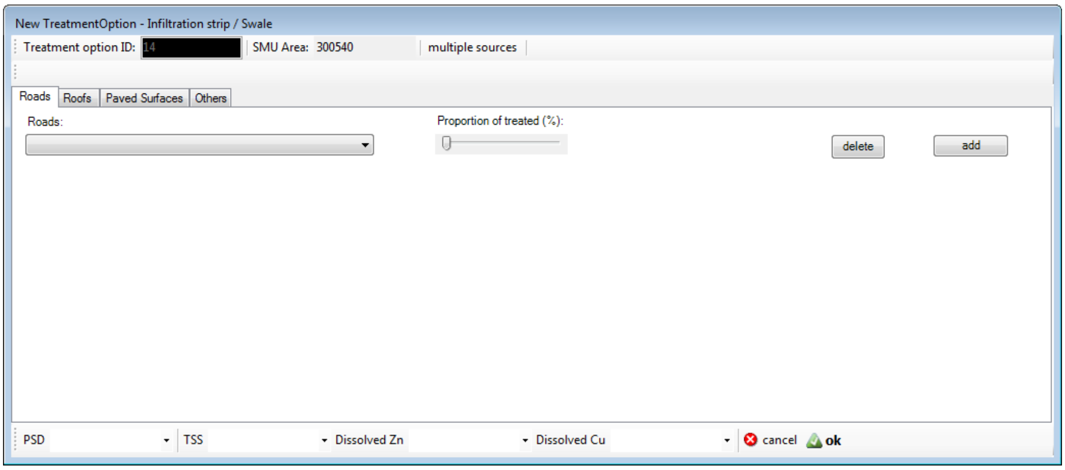
10. Select the PSD and level of treatment from the relevant drop down menus. In this example, medium removal of TSS and particulates and low removal of dissolved metals.



11. Click OK, the symbol for the treatment option will appear in the SMU.

12. Click on the third treatment option to be added, in this example, the *infiltration strip / swale* icon

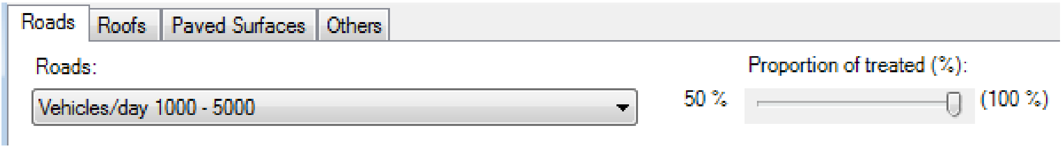
13. Click within the SMU boundary to open the *treatment set-up* window for the option.



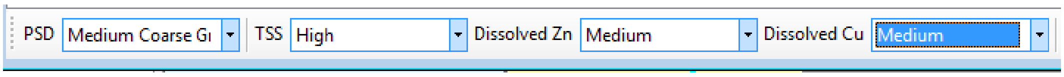
14. Click on the tab for the land cover type and select the land cover to be treated from the drop down menu.

15. Click on the land cover proportion slide. Note that for this example the slider has updated to include the proportion of the land cover already treated by catchpits and porous paving. In this example, the remaining 50% is treated by swales to give 100%

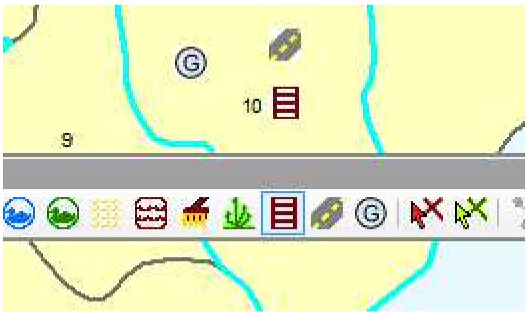
treatment of all road runoff. The land cover will no longer be available for subsequent treatment options.



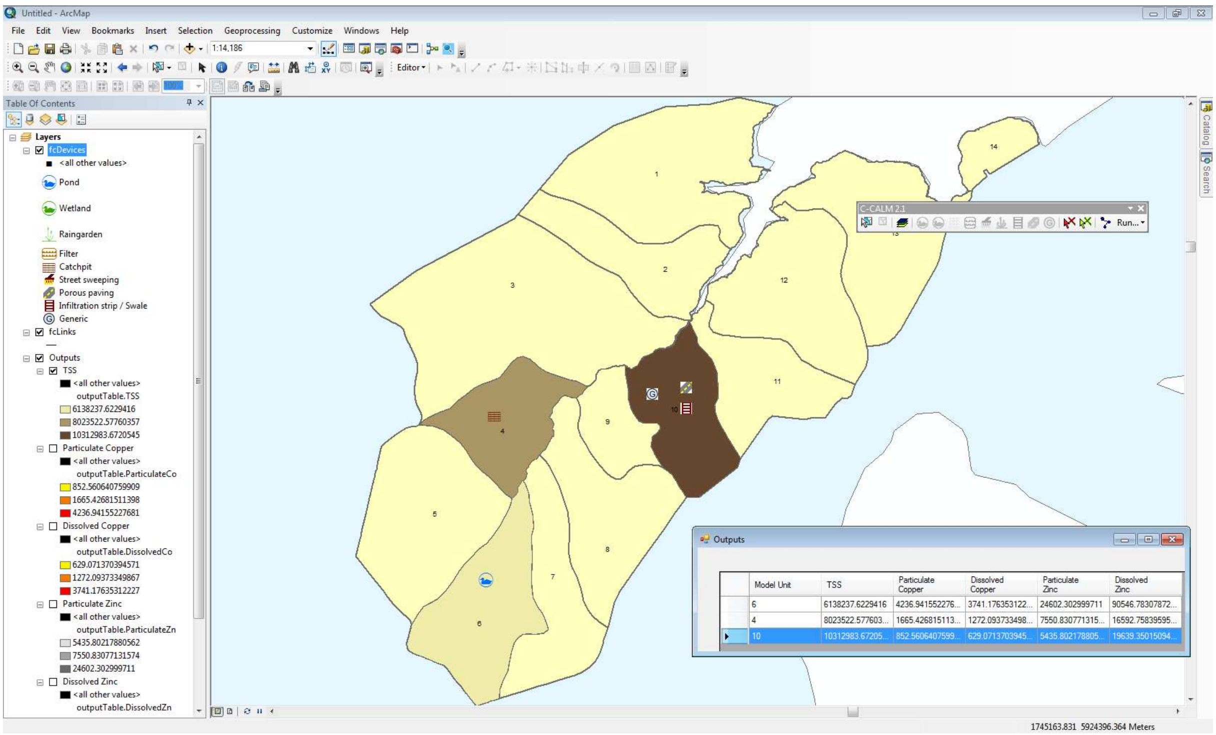
16. Select the PSD and level of treatment from the relevant drop down menus. In this example, high removal of TSS and particulates and medium removal of dissolved metals.



17. Click OK, the symbol for the treatment option will appear in the SMU.



18. Run C-CALM.



5.1.4 Multiple unlinked treatment options (raingardens, generic treatment and porous paving); multiple sources with split proportions

In this example (Figure 5-4), SMU 8 (new industrial, medium PSD) has a combination of treatment options for runoff from impervious surfaces. Raingardens treat 25% of roof runoff, and half each of runoff from paving and roads. A generic device (90% TSS and particulate removal, 60% of dissolved zinc and 40% of dissolved copper) treats the remaining 50% of road runoff and the remaining half of the paved surfaces are porous (low removal of TSS and medium removal of dissolved metals).

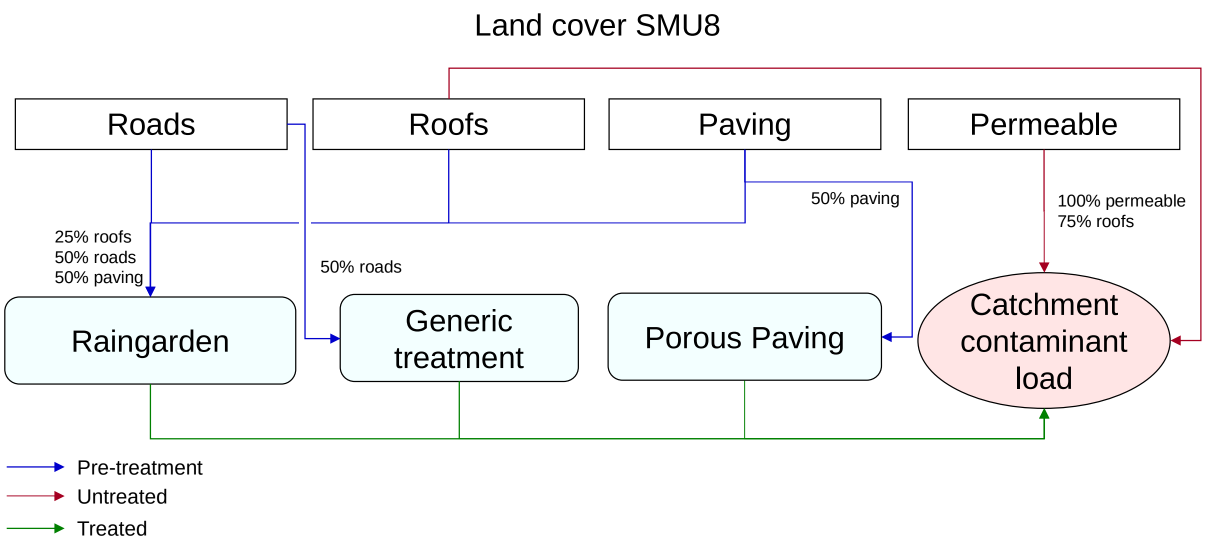


Figure 5-4: Stormwater treatment set-up for SMU 8.

Raingardens are usually designed to treat impervious surfaces with a recommended contributing area of around 1000 m^2 (e.g., Auckland Regional Council, 2003). The raingardens in this example are assumed to have the following parameters (with reference to the catchment properties in Appendix B):

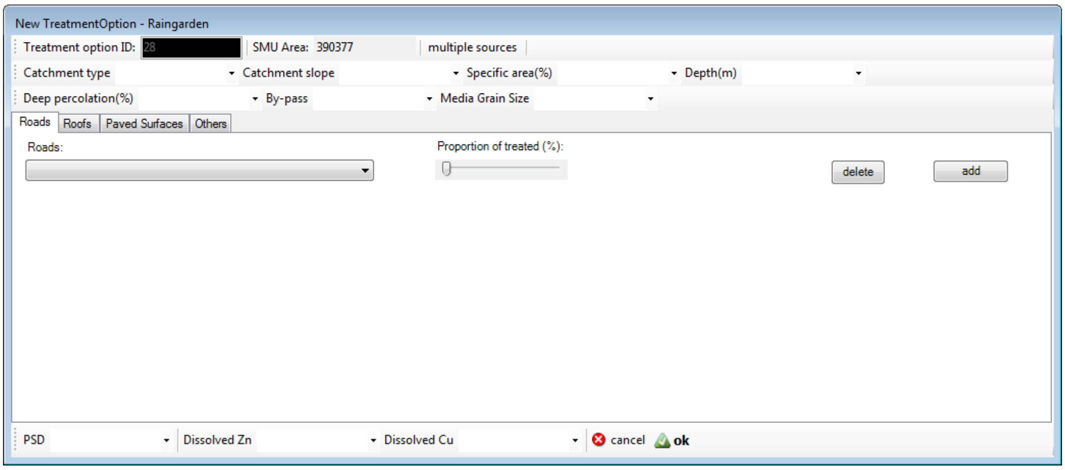
- Land use – industrial
- Slope to gutter – 0.01
- Specific area – 4 % or 40 m^2/1000 m^2
- Media depth – 1 m
- Deep percolation – 10 % (i.e., 10% of outflow drains directly to groundwater) By-pass – yes
- Median media grain size – 2 mm

The TSS and particulate removal efficiency for a raingarden with these characteristics in the C-CALM performance rules is 78%. The removal efficiency for dissolved metals is high.

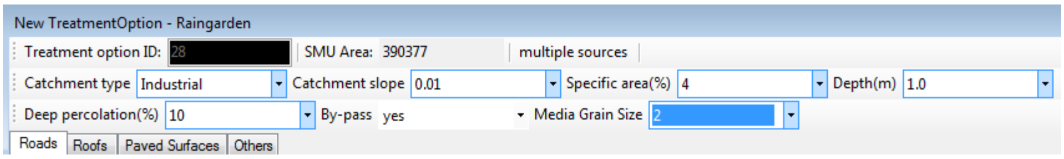
1. Close the output table and remove the output layers from the previous run. Highlight the *ccalm_units* shape file in the *TOC* to activate the treatment options and select the SMU to be simulated.

2. Click on the first treatment option to be added, in this example, the *raingarden* icon

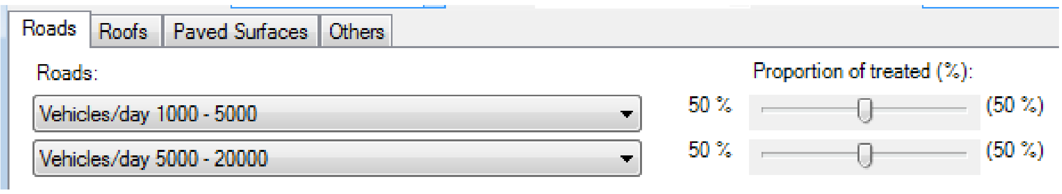
3. Click within the SMU boundary to open the *treatment set-up* window for the option.



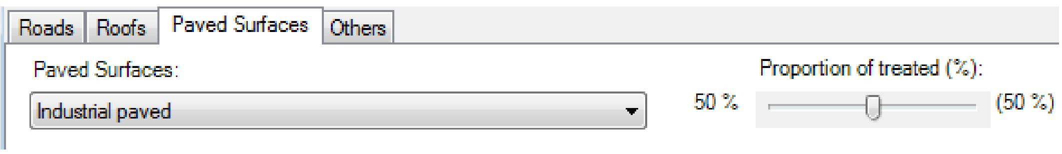
4. Fill in the raingarden parameters using the drop-down menus according to the design specifications (the specifications for this example are listed above)

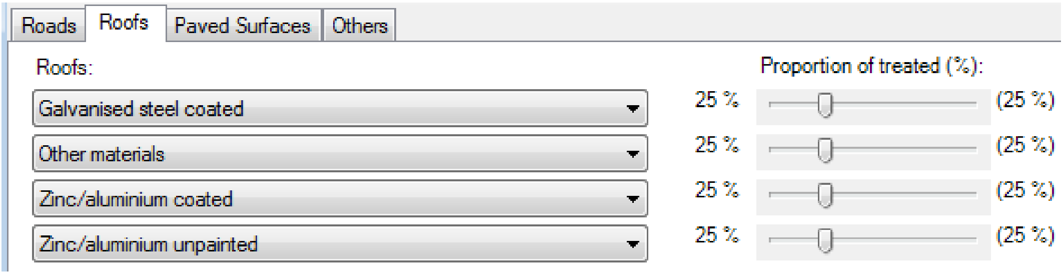


5. Select the tab for the first type of land cover to be treated with the option. Click on the drop down menu to see the land covers available for the selected cover type and select the option(s) required for the simulation. Use the slide counter to select the proportion of each cover type to be treated. In this example half of road runoff is treated by raingardens.

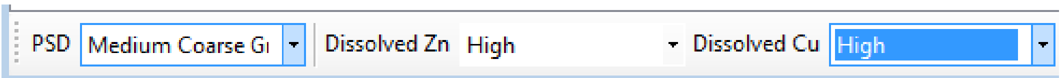


6. Continue through the cover type tabs until all of the land covers to be treated have been entered (in this case, half of the runoff from paved surfaces and 25% of runoff from roofs).

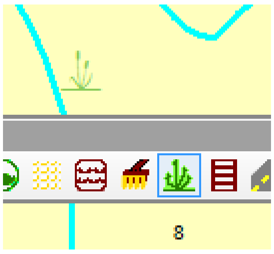




7. Select the PSD and level of removal efficiency for the dissolved metals and particulates where required (for this example, medium coarse PSD and high removal of dissolved metals).

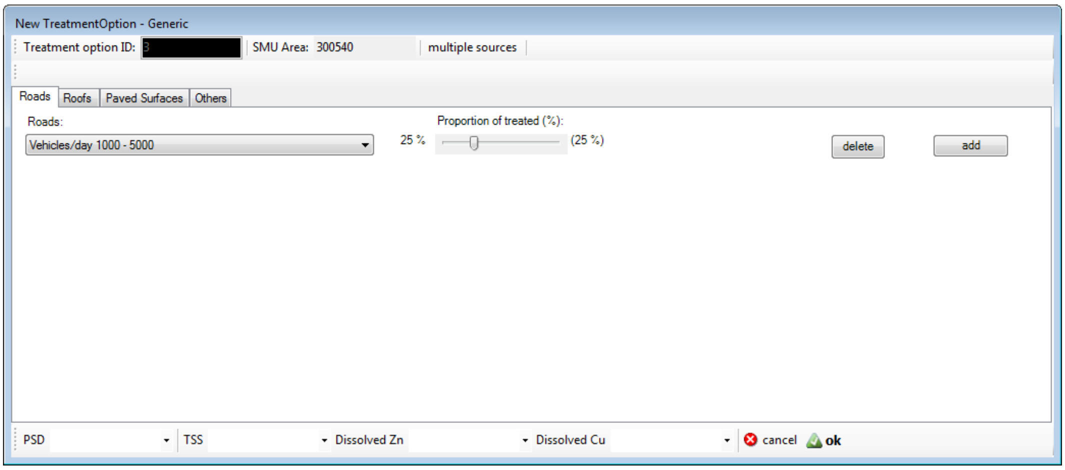


8. Click OK; the symbol for the treatment option will appear in the SMU.

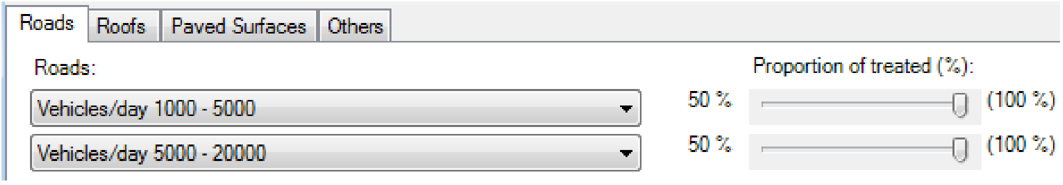


9. Click on the second treatment option to be added; in this example the *generic treatment* icon.

10. Click within the SMU boundary to open the *treatment set-up* window for the option.

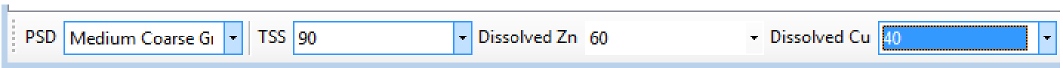


11. Select the tab for the first type of land cover to be treated with the option. In this example, the generic treatment treats only road runoff (50%). Note that the slider has been updated for the proportion of road runoff treated in the raingardens.



12. Continue through the cover type tabs until all of the land covers to be treated have been entered. In this example, there are no other land cover types treated.

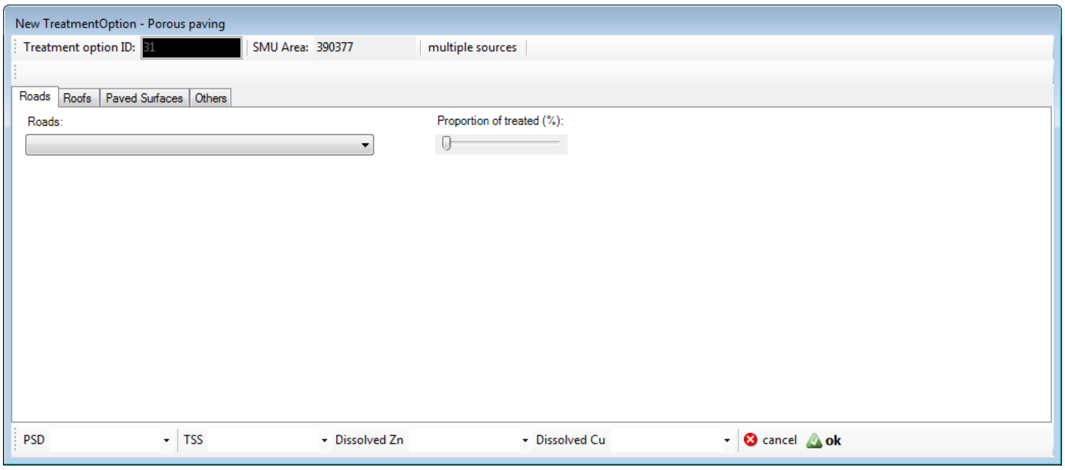
13. Select the PSD and level of removal efficiency for the generic treatment as required (in this example, 90% TSS and particulate removal, 60% of dissolved zinc and 40% of dissolved copper).



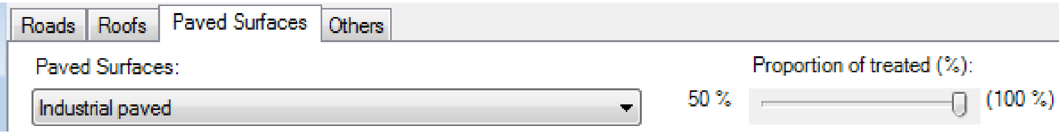
14. Click OK; the symbol for the treatment option will appear in the SMU.

15. Click on the third treatment option to be added; in this example, the *porous paving* icon.

16. Click within the SMU boundary to open the *treatment set-up* window for the option.

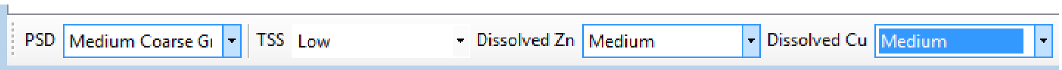


17. Select the tab for the type of land cover to be treated with the option. Note that porous paving is only available for roads and paved surfaces. In this example, 50% of the paved surfaces are porous. The slider has been updated to show that paved surfaces are also treated in another option giving 100% treatment (in this case the other treatment is 50% by raingardens).



18. Continue through the cover type tabs until all of the land covers to be treated have been entered. In this example, there are no other land cover types treated with infiltration strips.

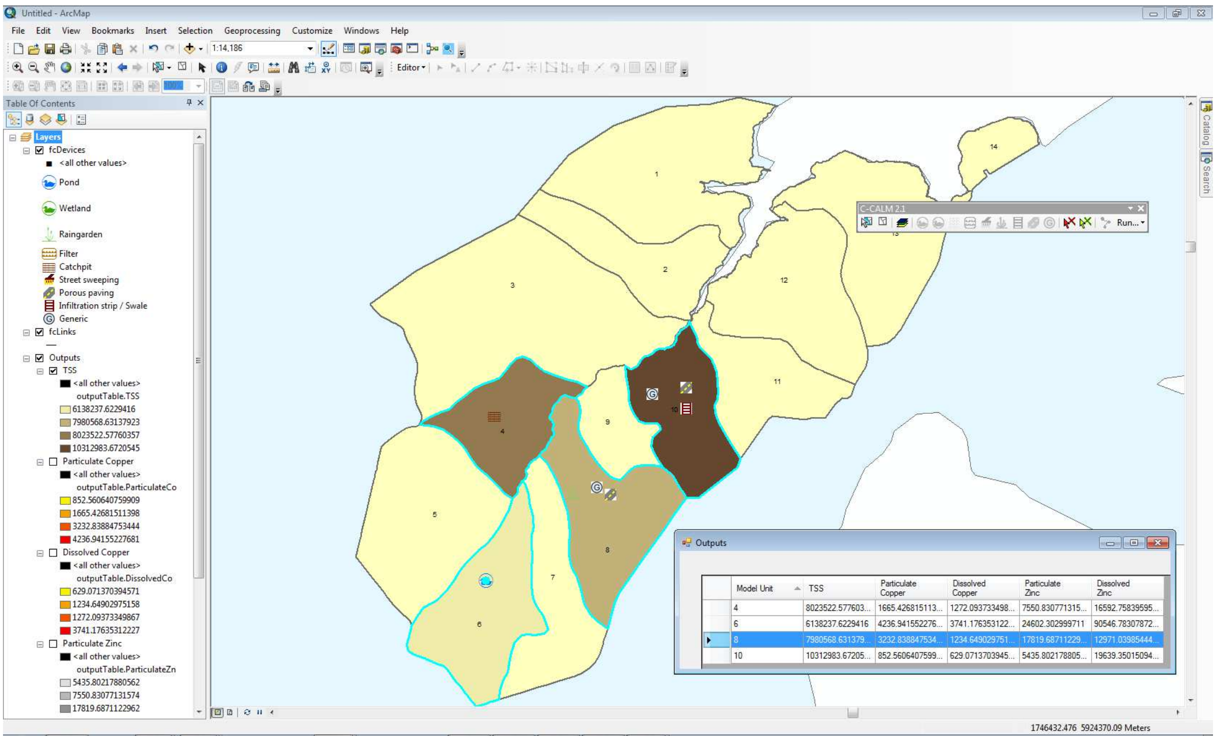
19. Select the PSD and level of removal efficiency for the dissolved metals and particulates where required (in this example, medium coarse PSD, low removal of TSS/particulates and medium removal of dissolved metals).

20. 

21. Click OK; the symbol for the treatment option will appear in the SMU.

22. Continue to add treatment options until the treatment scenario is complete.

23. Run C-CALM



5.2 Treatment trains

In the following examples, two or more treatment options in a single SMU [6]are linked in sequence to form a treatment train. C-CALM calculates the contaminant removal for each option in order of the links.

Downstream treatment options can take stormwater contaminants from an upstream treatment option from a combination of land covers and upstream treatment options or with the proportion of land cover split between different treatment options. More than one treatment train or combinations of treatment trains and separate options can be simulated within a SMU. Trains are created by drawing a link between treatment options.

C-CALM does not simulate the effects of peak flow reduction or attenuation on downstream removal processes.

5.2.1 One to one linked options (catchpits to proprietary filters); train only

This example (Figure 5-5) is very common for reticulated stormwater networks and has been applied to SMU 5 (old industrial, medium PSD). All of the runoff from roads and paved surfaces flows via catchpits (no inserts) to proprietary filters. In C-CALM, the difference between proprietary filters and sand filters is manifested in the choice of removal efficiency – here the choice of high removal is used on the assumption that the filters are adequately sized, well maintained and contain an activated medium for dissolved metal removal.

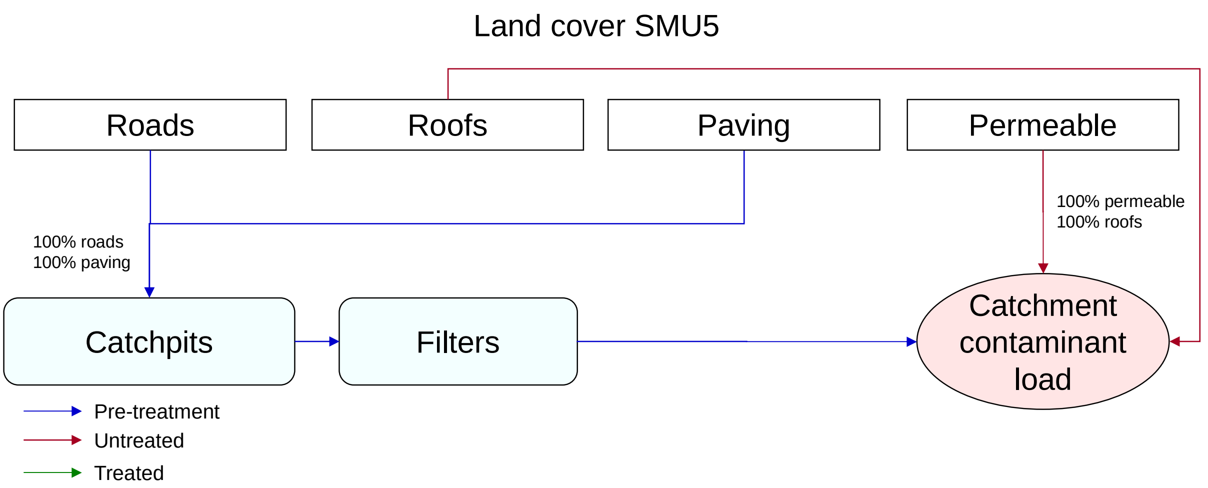


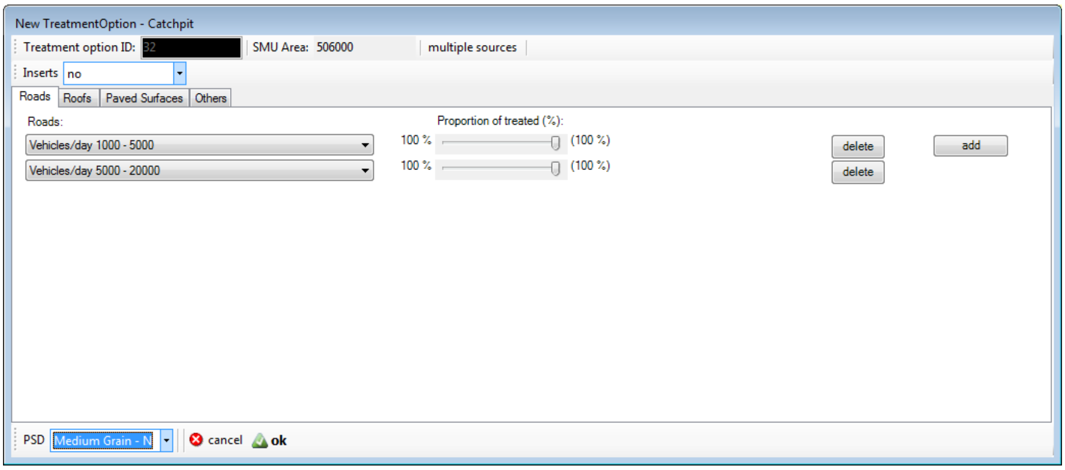
Figure 5-5: Stormwater treatment set-up for SMU 5.

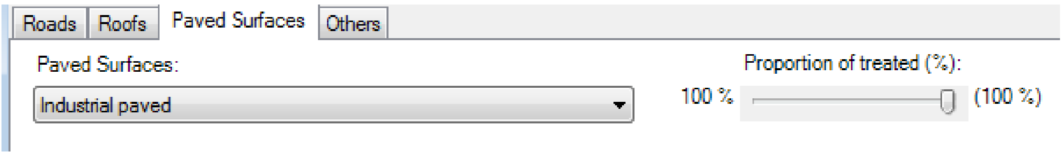
1. Close the output table and remove the output layers from the previous run. Highlight the *ccalm_units* shape file in the *TOC* to activate the treatment options and select the SMU to be simulated.

2. Click on the first (upstream) treatment option; in this case the *catchpit* icon

[6] While it is possible to link across treatment across SMU boundaries, this will cause C-CALM to give incorrect treatment estimates.

3. Click within the SMU boundary to open the *treatment set-up* window for the option and fill it in according to the scenario described above.

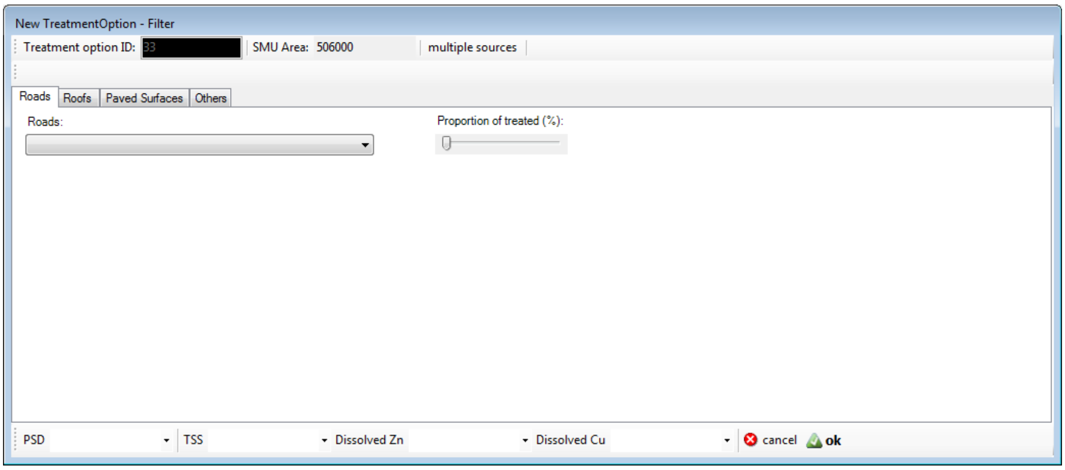




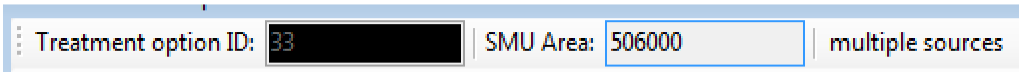
4. Click OK, the symbol for the treatment option will appear in the SMU.

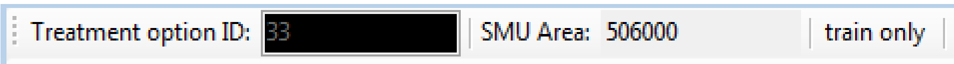
5. Click on the second (downstream) treatment option, in this case the *filter* icon

6. Click within the SMU boundary to open the *treatment set-up* window for the option.

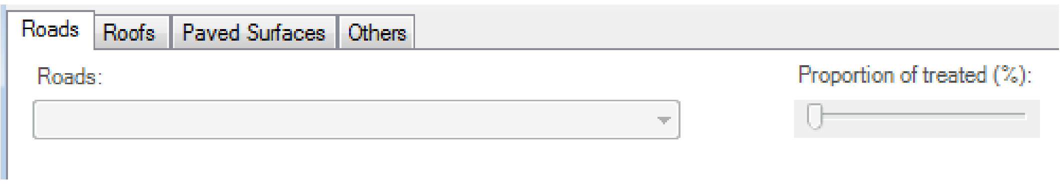


7. In this example, the filters only receive stormwater that has been pre-treated in catchpits. Click on the *multiple sources* button near the top of the *treatment set-up* window (this is the default which allows users to input land covers to be treated) to activate *train only* mode.

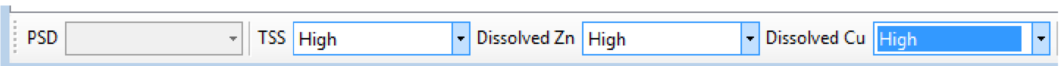




8. The land cover and PSD drop-down menus will be deactivated, and C-CALM will direct the outputs of the upstream option to the downstream option once the two are linked.



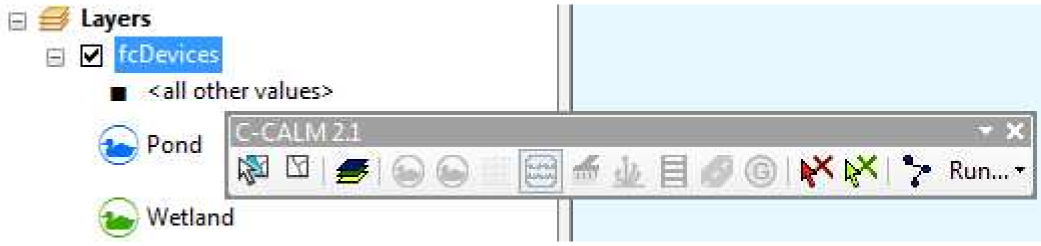
9. Select the level of removal efficiency for the dissolved metals and particulates where required (in this example, high removal of all contaminants). Note that the drop-down menu for the choice of PSD is not active.



10. Click OK, the symbol for the treatment option will appear in the SMU.

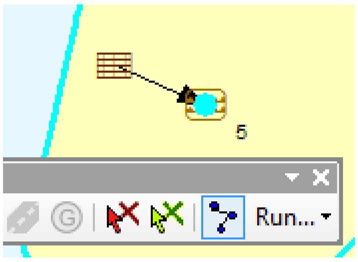
11. Continue to add treatment options until the treatment scenario is complete. In this example there are no more treatment options to add. Once the treatment options are in place they can be linked for form trains.

12. To link the treatment options, highlight the *fcdevices* shape file in the *TOC* to activate the model tools.



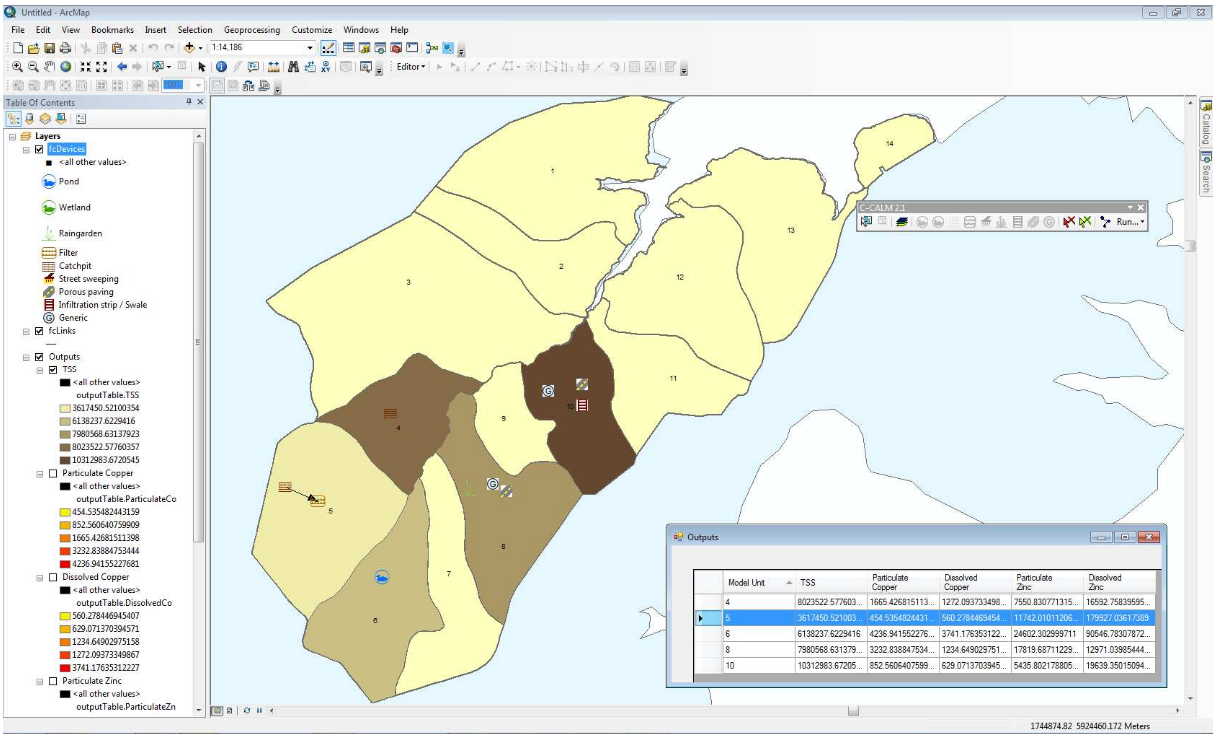
13. Trains are created by drawing links between treatment options. Click on the *links* icon.

14. Click and drag from the centre of the upstream option to the centre of the downstream option. Double-click. A dashed red line will flash between the options and will then become a black arrow, the direction of which shows the direction of the link.



Be careful not to link an upstream treatment option with more than one downstream option; otherwise C-CALM will will double count the contaminants.

15. Run C-CALM

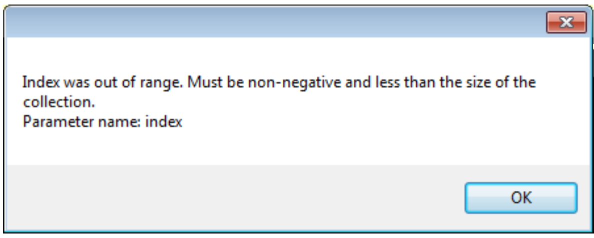


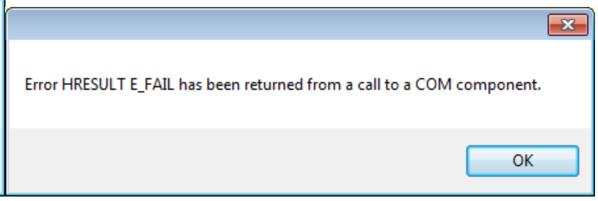
WARNING: Do not link:

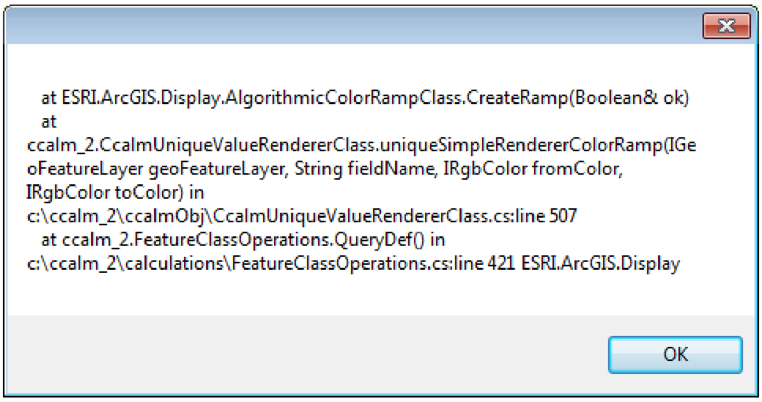
- An upstream treatment option to two or more downstream options. If a treatment option drains to two types of treatment, input the treatment twice in separate trains. See Section 0 for an example of this kind of arrangement.
- Across SMUs, all linked treatment options must be in the same SUM.

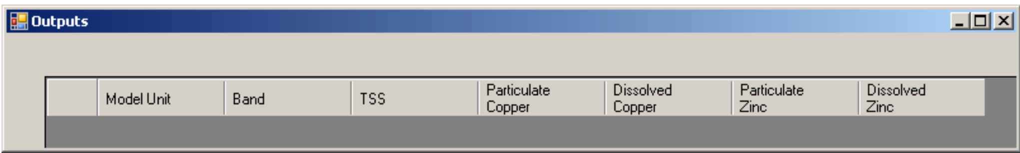
While C-CALM will work in either case, the results will be incorrect.

TROUBLE SHOOTING: When I try to run C-CALM with a *train only* treatment option I get these error messages and no results. Why?

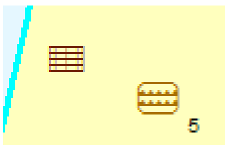




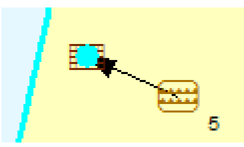




A *train only* down-stream treatment option has been inserted into the treatment train but is the option is not linked to an upstream treatment option or has been linked in the wrong direction.



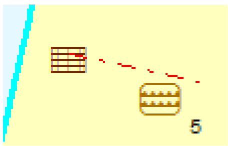
or



Close the Outputs table.

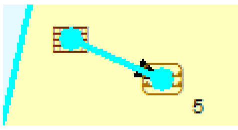
Check that the options in a train are correctly linked, ensure that there is an arrow from upstream to downstream options. See Section 0 for instructions on removing links if the link is in the wrong direction.

TROUBLE SHOOTING: I tried to link, but the dashed red line remains and I don't get a black arrow.



The dashed line means that the link was not clicked inside the centre tolerance buffer for the one or both of the treatment options. Draw the link again taking care to click from centre to centre – the link arrow should appear and the dashed line will be deleted automatically.

TROUBLE SHOOTING: Some of my treatment options and links are highlighted.



C-CALM may automatically select and highlight treatment options and links. This will not affect model results. Highlighting can be removed for display by clicking the clear selection button (you will need to reselect the SMU for simulation).

5.2.2 One to one linked options (street sweeping to generic treatment); multiple sources with split proportions

In this example (Figure 5-6), stormwater from SMU 12 (new industrial, medium coarse PSD) is treated by good housekeeping (street sweeping) and a generic treatment device (80% TSS and particulate removal, 50% dissolved zinc removal and 35% dissolved copper removal). Street sweeping pre-treats runoff from roads and half of paved surfaces before it reaches the generic treatment. The remaining runoff from paved surfaces and a quarter of roof runoff is also drained to the swale but is not pre-treated.

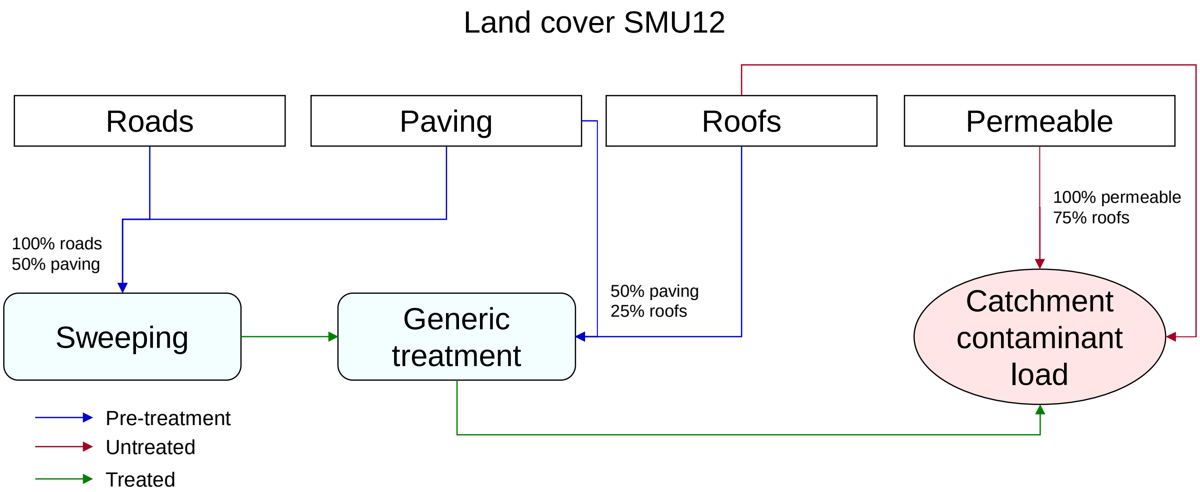
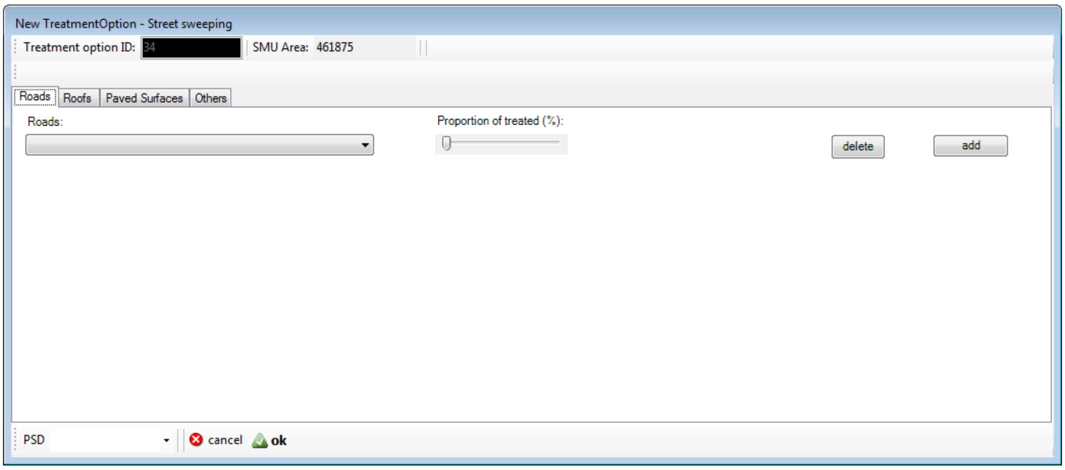


Figure 5-6: Stormwater treatment set-up for SMU 12.

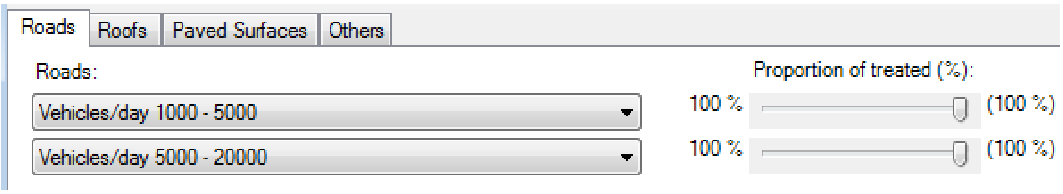
1. Close the output table and remove the output layers from the previous run. Highlight the *ccalm_units* shape file in the *TOC* to activate the treatment options and select the SMU to be simulated.

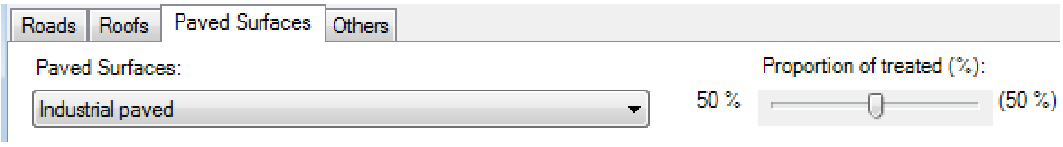
2. Click on the first (upstream) treatment option; in this case the *street sweeping* icon.

3. Click within the SMU boundary to open the *treatment set-up* window for the option.



4. Select the land covers and their respective treatment proportions to be treated by the train. Note that for street sweeping, only roads and paved surfaces are available. In this example all of the roads and half of the paved surfaces are swept.



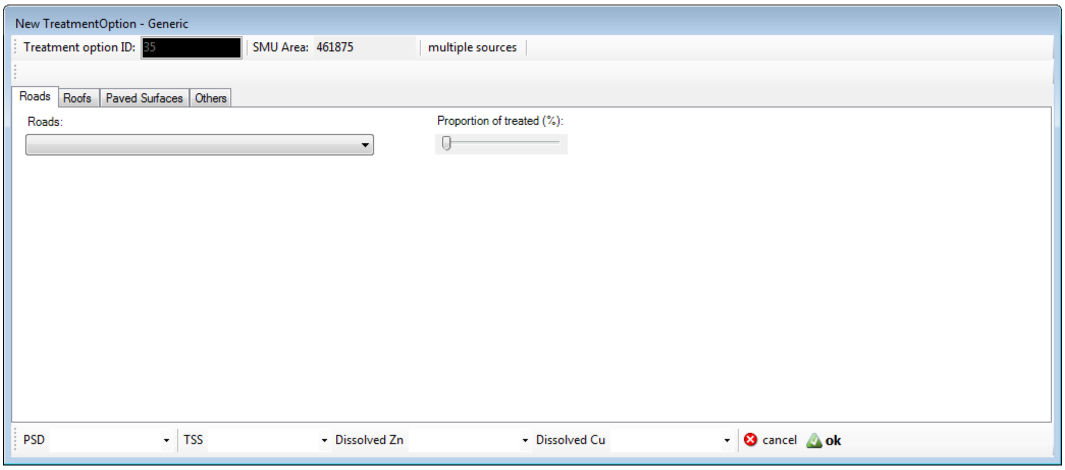


5. Choose the PSD of sediments being treated. Note: street sweeping assumes that dissolved metals are not treated.

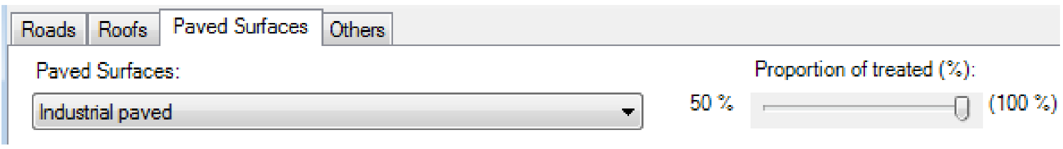
6. Click OK; the symbol for the treatment option will appear in the SMU.

7. Click on the second (downstream) treatment option, in this case the *generic treatment* icon.

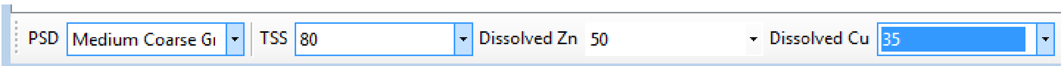
8. Click within the SMU boundary to open the *treatment set-up* window for the option.



9. Select the land covers and their respective treatment proportions to be treated by the second option but not the first. The pre-treated runoff (in this case, road runoff and 50% of runoff from paved surfaces) will be added to the downstream treatment once a link is made between the two options.

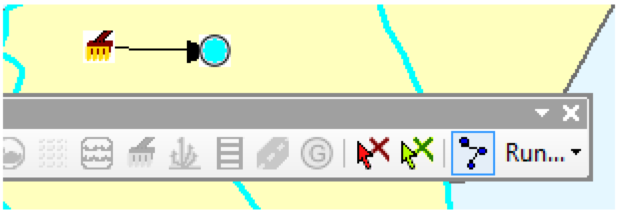


10. Select the PSD and level of treatment required. (in this example, 80% TSS and particulate removal, 50% dissolved zinc removal and 35% dissolved copper removal)

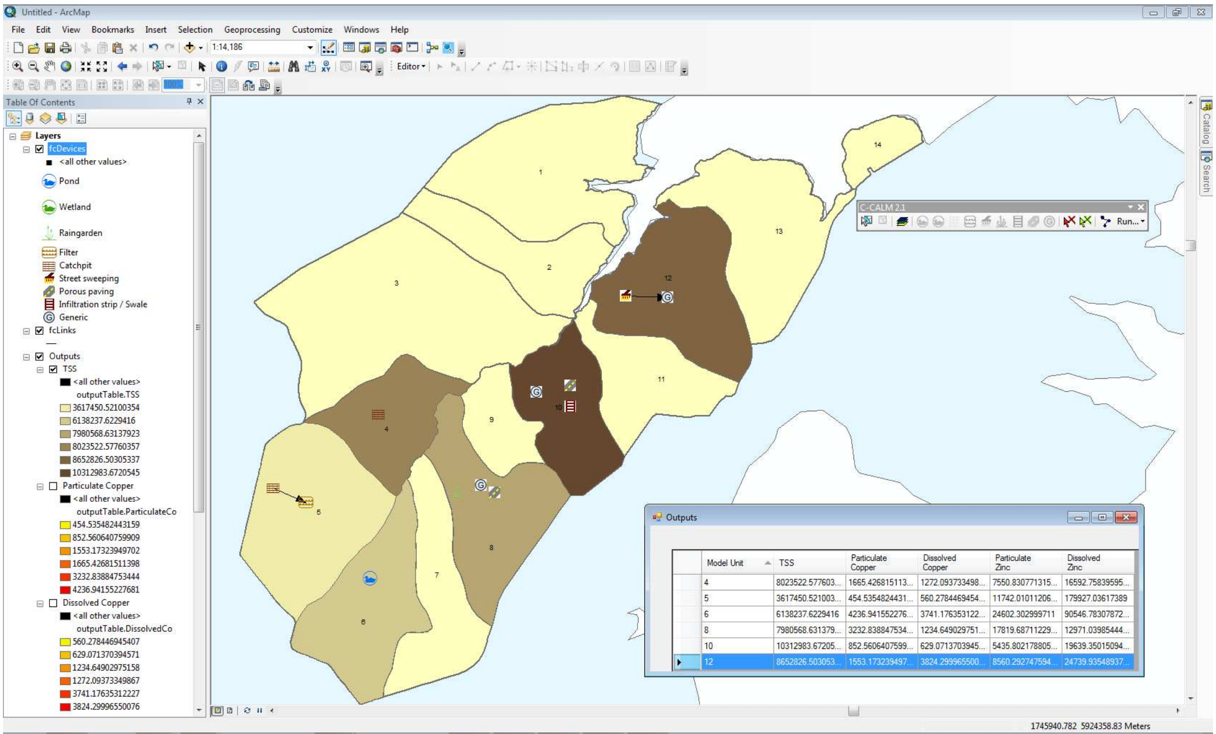


11. Click OK; the symbol for the treatment option will appear in the SMU.

12. Highlight the *fcdevices* shape file in the *TOC* to activate the model tools; click the *link* icon and link the options according to the instructions given in Example 5.2.1.



13. Run C-CALM



5.2.3 Treatment trains with multiple links (generic treatment, infiltration surfaces and raingardens and to wetland)

In this example (Figure 5-7), runoff from the impervious surfaces found in SMU 11 (low density residential, medium PSD) is pre-treated variously by generic treatment, raingardens and infiltrations surfaces before treatment in an end-of-line wetland. All roof runoff is treated by raingardens. Road runoff is pre-treated by infiltration (low for all contaminants) and the half of the paved surfaces treated with the generic option (60% removal of all contaminants).

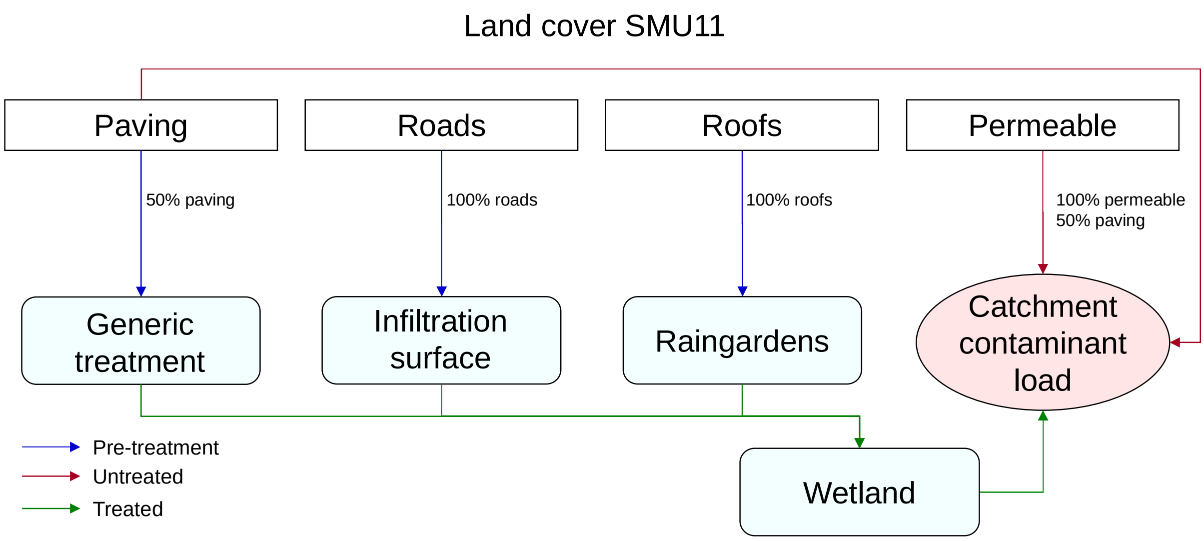


Figure 5-7: Stormwater treatment set-up for SMU 11.

The raingardens are assumed to have the following parameters:

- Land use – residential
- Slope to gutter – 0.05
- Specific area – 2 % or 20 m^2/1000 m^2
- Media depth – 1 m
- Deep percolation – 0 (i.e., lined with no percolation to groundwater)
- By-pass – yes
- Median media grain size – 3 mm

The removal efficiency of TSS/particulates for a raingarden with these characteristics in the C-CALM performance rules is 71%. The removal efficiency for dissolved metals is high.

The wetland is assumed to have the following:

- Land use – residential
- Imperviousness – 40 % (representing 36.4 for SMU)
- Slope to gutter – 0.05
- Specific area – 1% or 100 m^2/ha
- (i.e., a pond area of around 1000 m^2 serving 10.5 ha of impervious surfaces)
- Hydraulic Efficiency – 8 (excellent, see Appendix Three)
- Depth/invert level – 1 m
- Weir width – 2 m
- Extended detention – yes

This combination gives the following treatment efficiency (%) in the C-CALM database:

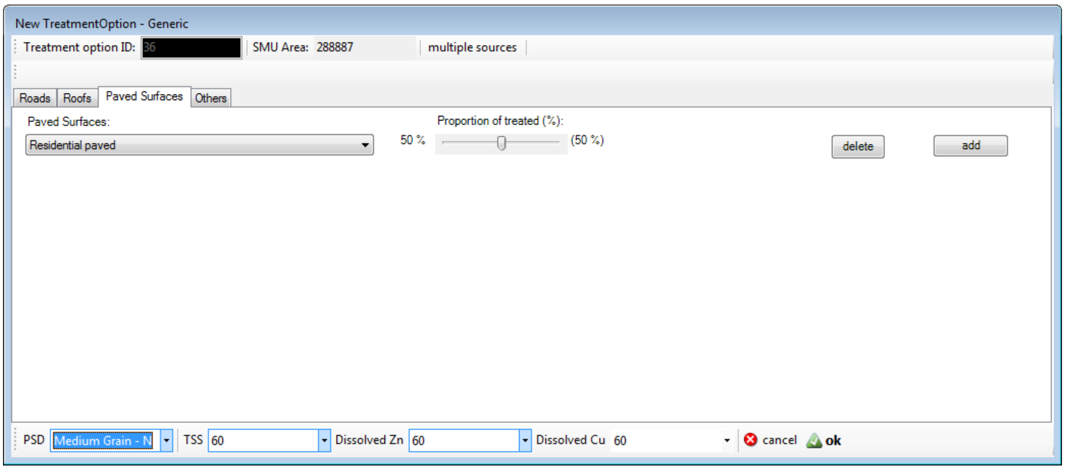
Band1	Band2	Band3	Band4	Band5	Band6	Band7	Band8	Band9
8	10	25	67	96	99	99	99	99

The removal efficiency for dissolved metals is medium.

1. Close the output table and remove the output layers from the previous run. Highlight the *ccalm_units* shape file in the *TOC* to activate the treatment options and select the SMU to be simulated.

2. Click on the first upstream treatment option, in this case the *generic treatment* icon.

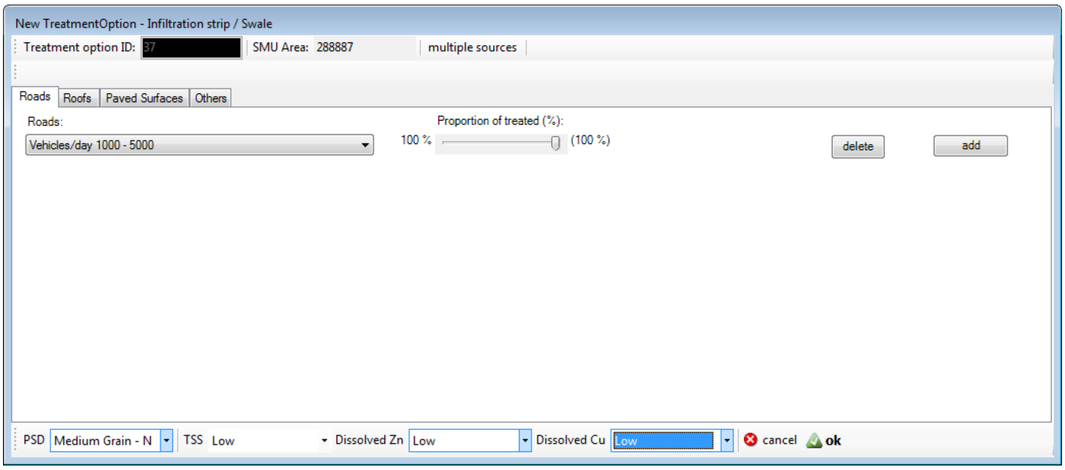
3. Click within the SMU boundary to open the *treatment set-up* window for the option and fill as required (in this case, 50% of paving to be treated with 60% removal or all contaminants).



4. Click OK, the symbol for the treatment option will appear in the SMU.

5. Click on the second upstream treatment option, in this case the *swales / infiltration strip* icon.

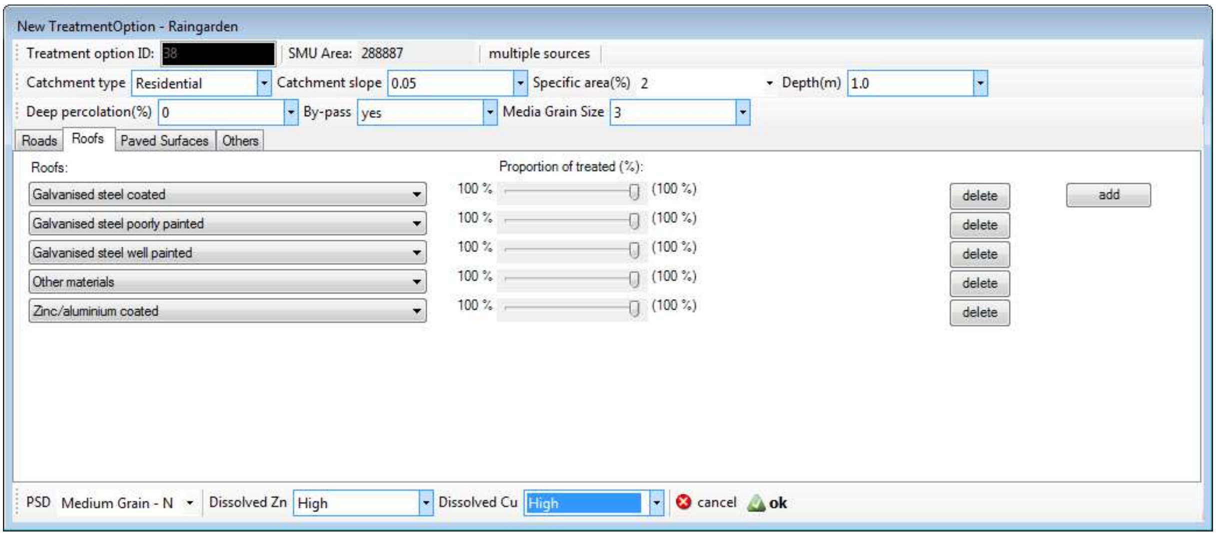
6. Click within the SMU boundary to open the *treatment set-up* window for the option and fill as required (in this case all roads to have low level of treatment for all contaminants)



7. Click OK; the symbol for the treatment option will appear in the SMU.

8. Click on the third upstream treatment option, in this case the *raingarden* icon.

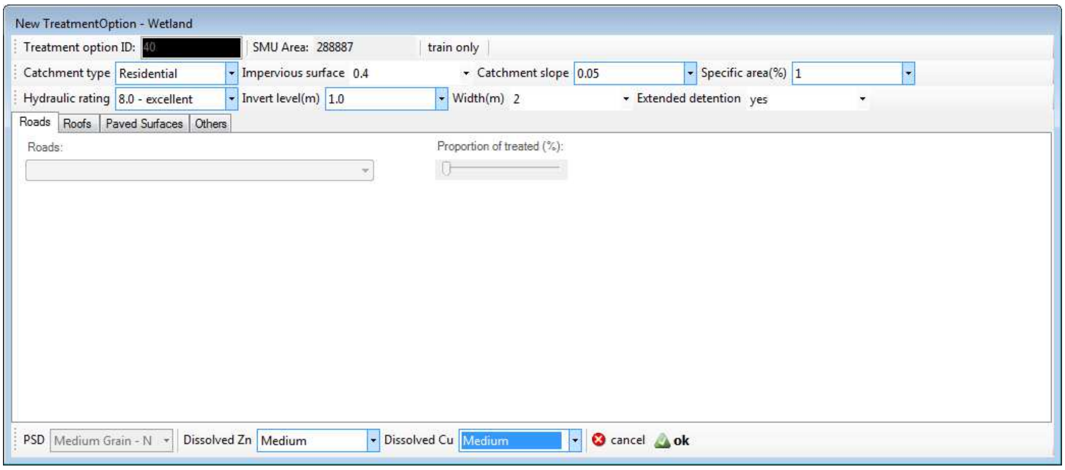
9. Click within the SMU boundary to open the *treatment set-up* window for the option and fill as required.



10. Click OK; the symbol for the treatment option will appear in the SMU.

11. Click on the downstream treatment option, in this case the *wetland* icon.

12. Click within the SMU boundary to open the *treatment set-up* window for the option and fill as required. In this example, the wetland receives inflow via the other treatment options and is set to *train only*.

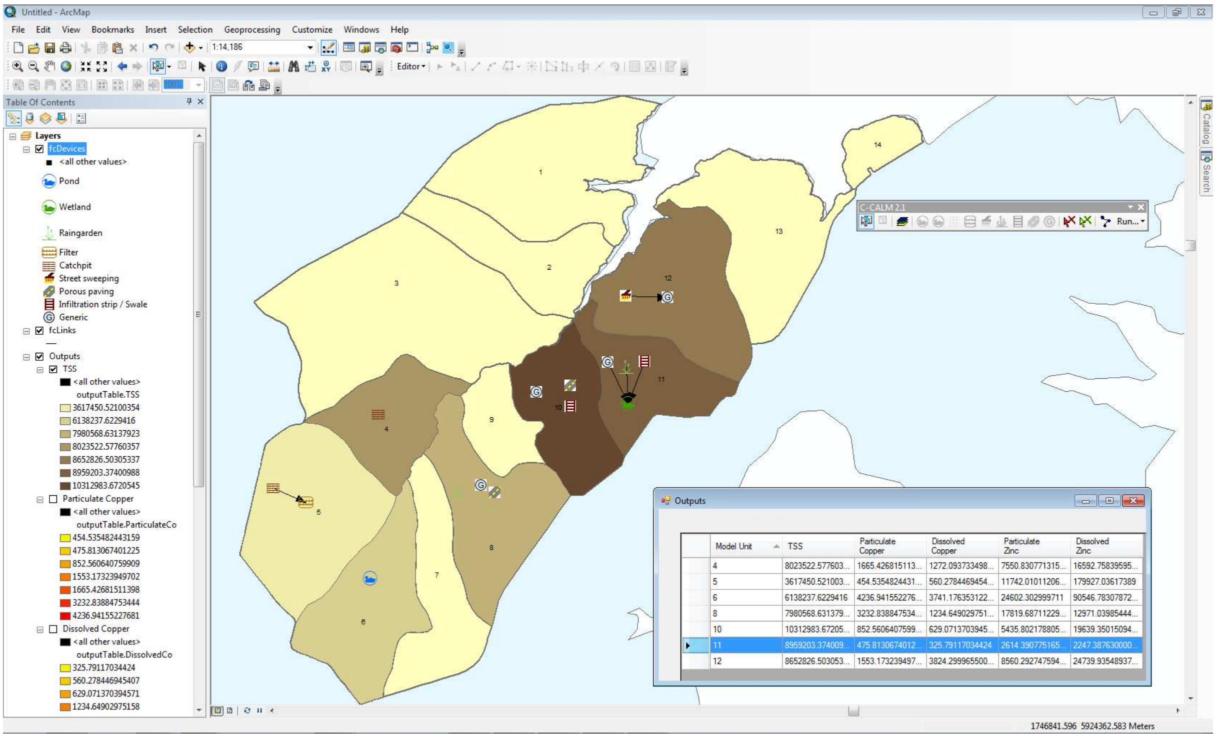


13. Click OK; the symbol for the treatment option will appear in the SMU.

14. Continue to add treatment options until the treatment scenario is complete. Once the treatment options are in place, they can be linked for form trains.

15. Highlight the *fcdevices* shape file in the *TOC* to activate the model tools, click the *link* icon and link the options by clicking a dragging from the centre of the upstream option to the the downstream option. Double click to create the link. In this case, the generic treatment, infiltration surfaces and raingarden are all linked to the wetland.

16. Run C-CALM.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Layers
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Pond
Wetland
Raingarden
Filter
Catchpit
Street sweeping
Porous paving
Infiltration strip / Swale
Generic
fcLinks
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8652826.50305337
8959203.37400988
10312983.6720545
Particulate Copper
<all other values>
outputTable.ParticulateCo
454.535482443159
475.813067401225
852.560640759909
1553.17323949702
1665.42681511398
3232.83884753444
4236.94155227681
Dissolved Copper
<all other values>
outputTable.DissolvedCo
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560.278446945407
629.071370394571
1234.64902975158
C-CALM 2.1
Run...
Outputs
Model Unit | TSS | Particulate Copper | Dissolved Copper | Particulate Zinc | Dissolved Zinc
4 | 8023522.577603... | 1665.426815113... | 1272.093733498... | 7550.830771315... | 16592.75839595...
5 | 3617450.521003... | 454.5354824431... | 560.2784469454... | 11742.01011206... | 179927.03617389
6 | 6138237.6229416 | 4236.941552276... | 3741.176353122... | 24602.302999711 | 90546.78307872...
8 | 7980568.631379... | 3232.838847534... | 1234.649029751... | 17819.68711229... | 12971.03985444...
10 | 10312983.67205... | 852.5606407599... | 629.0713703945... | 5435.802178805... | 19639.35015094...
11 | 8959203.374009... | 475.8130674012... | 325.79117034424 | 2614.390775165... | 2247.387630000...
12 | 8652826.503053... | 1553.173239497... | 3824.299965500... | 8560.292747594... | 24739.93548937...
1746841.596 5924362.583 Meters

5.2.4 Train and separate treatment options (catchpit inserts, sand filters, porous paving and swales)

C-CALM allows combinations of treatment trains and separate treatment options. This example (Figure 5-8) demonstrates the use of a train with two separate treatment options to treat runoff from SMU 7 (old industrial, medium coarse PSD). Runoff from main roads (5000-20000 v.p.d.) is treated in catchpits with inserts leading to sand filters (low treatment for all contaminants). Half of the paved surfaces are porous (medium treatment for all contaminants). The other half of paved surfaces drain via swales (assumed to have high treatment TSS and particulates and medium for the dissolved metals), which also take 25% of roof runoff and runoff from minor roads.

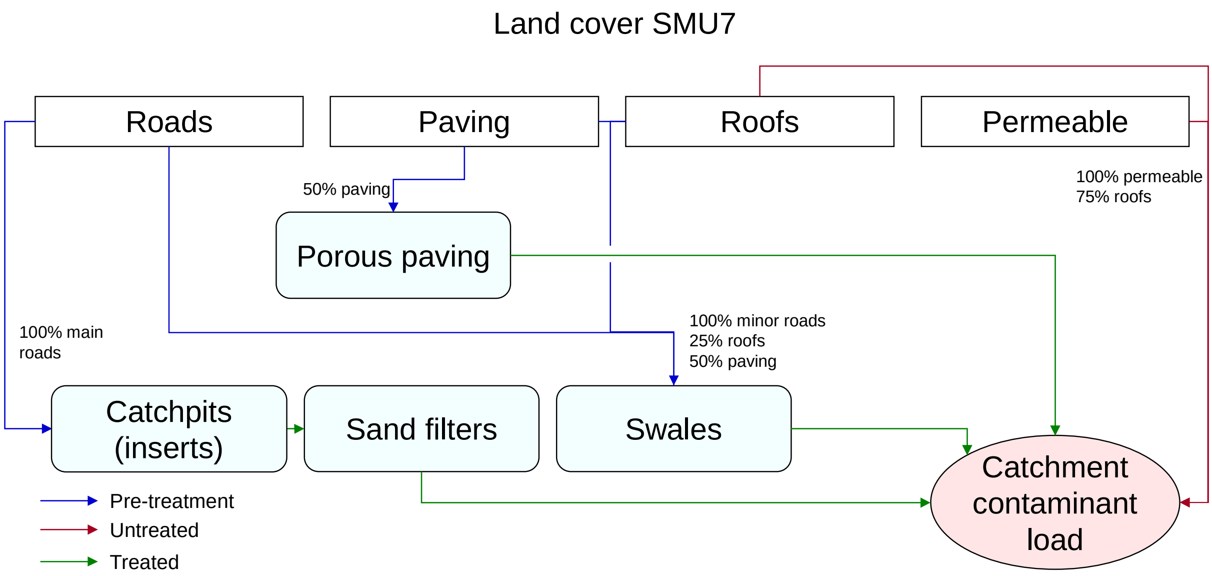
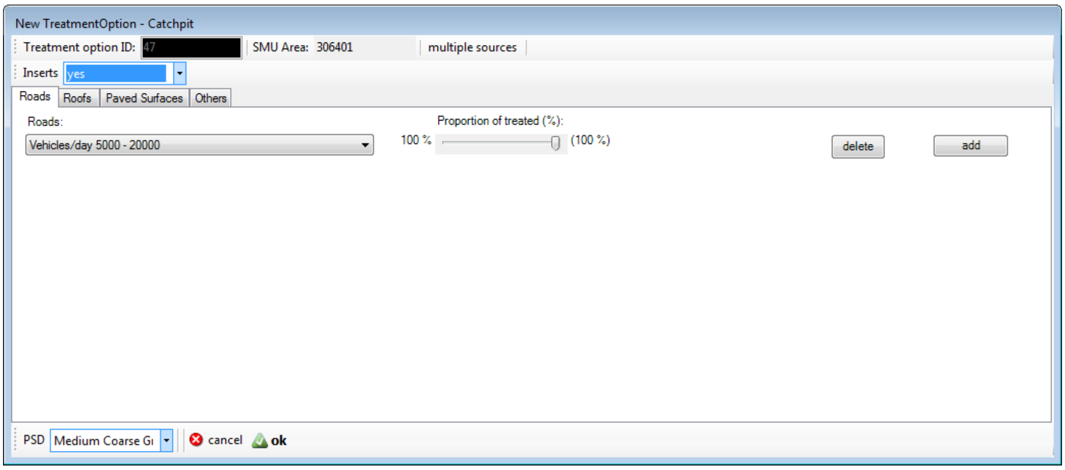


Figure 5-8: Stormwater treatment set-up for SMU 7.

1. Close the output table and remove the output layers from the previous run. Highlight the *ccalm_units* shape file in the *TOC* to activate the treatment options and select the SMU to be simulated.

2. Click on the first (upstream) treatment option, in this case the *catchpits* icon

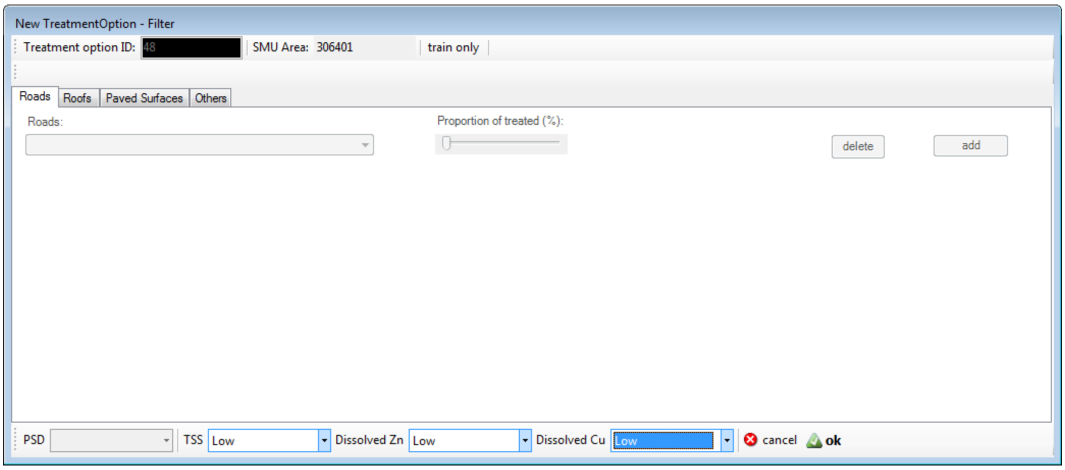
3. Click within the SMU boundary to open the *treatment set-up* window for the option and fill as required.



4. Click OK; the symbol for the treatment option will appear in the SMU.

5. Click on second treatment option, in this case the *filter* icon

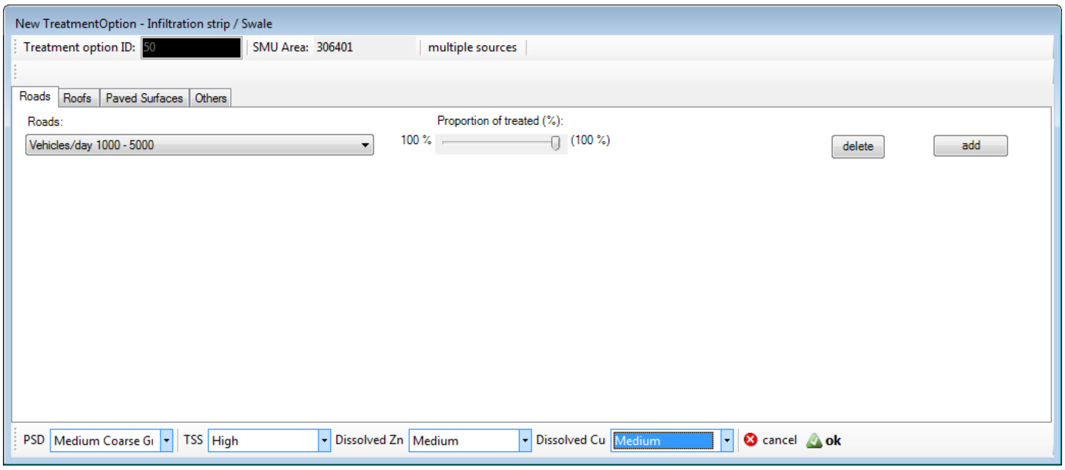
6. Click within the SMU boundary to open the *treatment set-up* window for the option and fill as required.

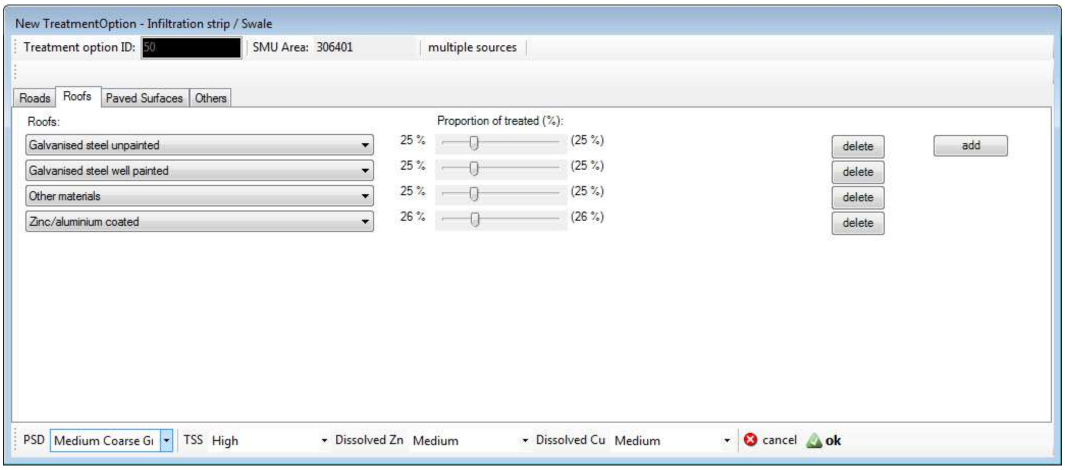


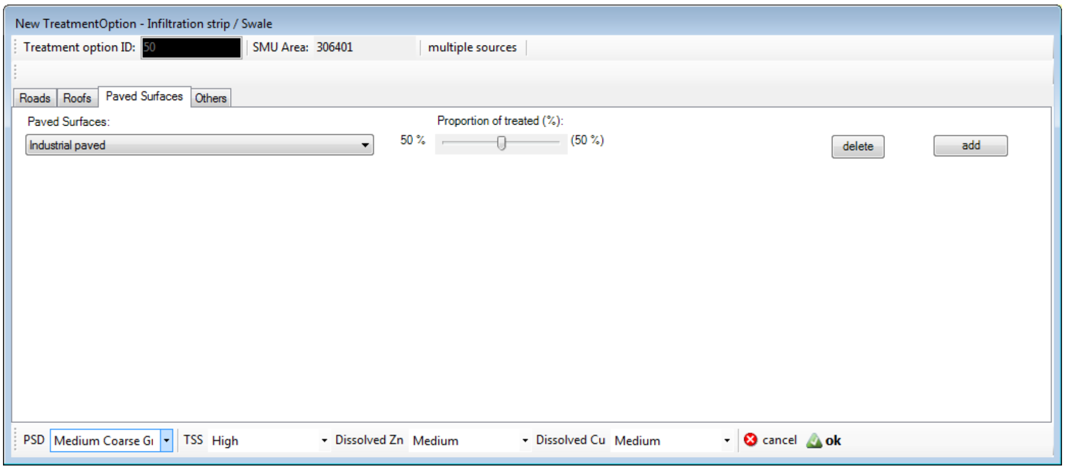
7. Click OK; the symbol for the treatment option will appear in the SMU.

8. Click on third treatment option, in this case the *swales / infiltration strip* icon

9. Click within the SMU boundary to open the *treatment set-up* window for the option and fill as required.



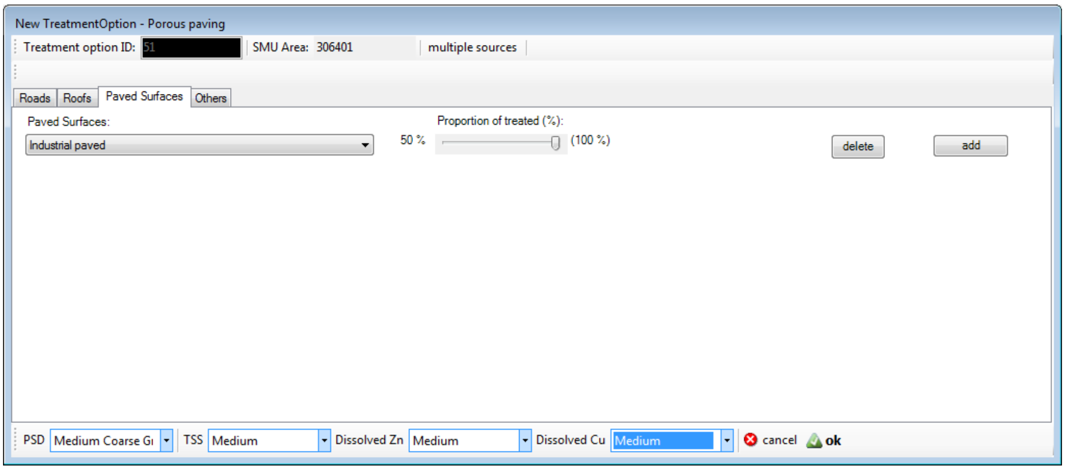




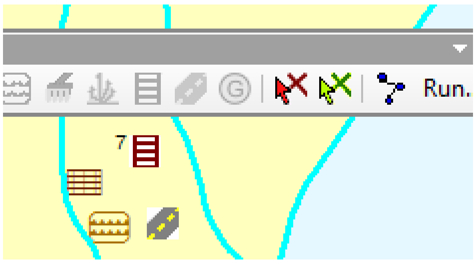
10. Click OK; the symbol for the treatment option will appear in the SMU.

11. Click on fourth treatment option, in this case the *porous paving* icon

12. Click within the SMU boundary to open the *treatment set-up* window for the option and fill as required.

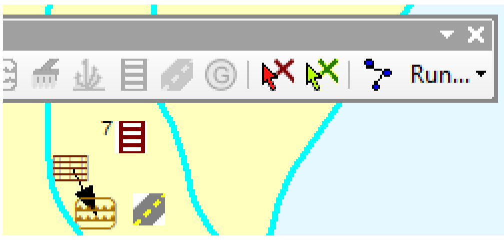


13. Click OK; the symbol for the treatment option will appear in the SMU.

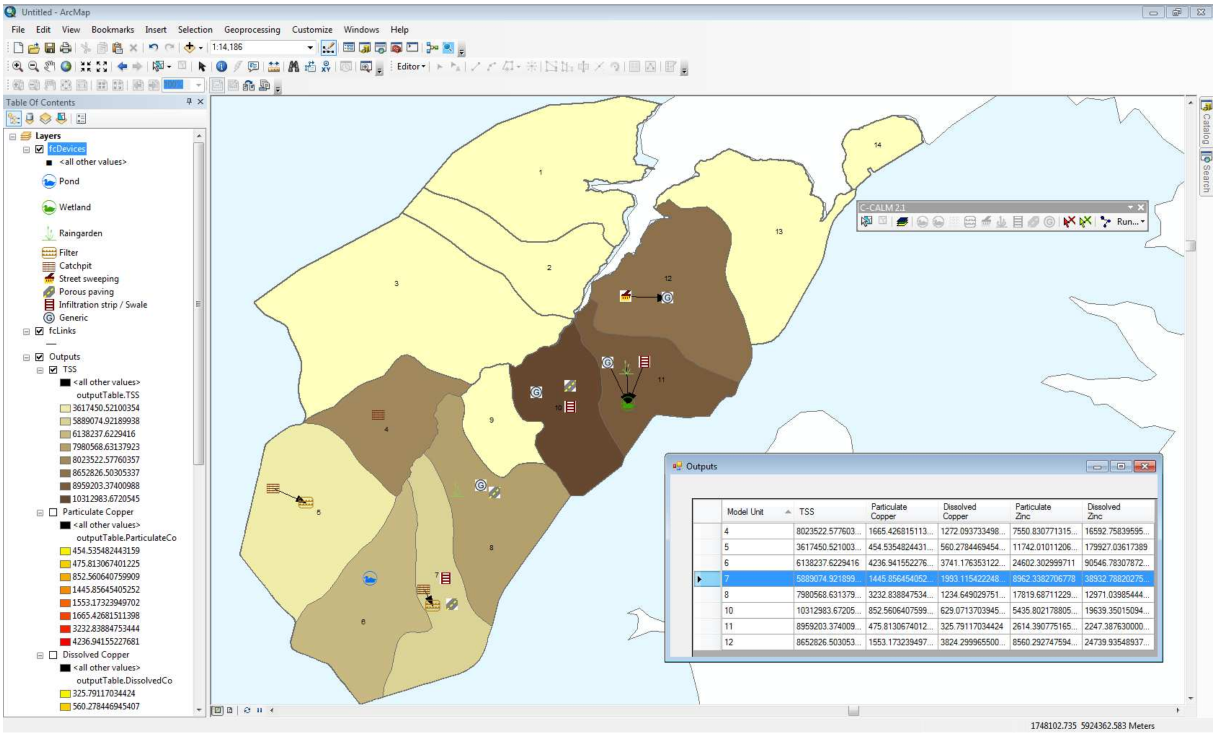


14. Continue to add treatment options until the treatment scenario is complete. Once the treatment options are in place, they can be linked for form trains.

15. Highlight the *fcdevices* shape file in the *TOC* to activate the model tools, click the *link* icon and link the options. In this case the catchpits are linked to filters while the porous paving and swales are not part of the train and are not linked.



16. Run C-CALM.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File Edit View Bookmarks Insert Selection Geoprocessing Customize Windows Help
1:14,186
Editor
Table Of Contents
Layers
fcDevices
<all other values>
Pond
Wetland
Raingarden
Filter
Catchpit
Street sweeping
Porous paving
Infiltration strip / Swale
Generic
fcLinks
Outputs
TSS
<all other values>
outputTable.TSS
3617450.52100354
5889074.92189938
6138237.6229416
7980568.63137923
8023522.57760357
8652826.50305337
8959203.37400988
10312983.6720545
Particulate Copper
<all other values>
outputTable.ParticulateCo
454.535482443159
475.813067401225
852.560640759909
1445.85645405252
1553.17323949702
1665.42681511398
3232.83884753444
4236.94155227681
Dissolved Copper
<all other values>
outputTable.DissolvedCo
325.79117034424
560.278446945407
C-CALM 2.1
Run...
Outputs
Model Unit | TSS | Particulate Copper | Dissolved Copper | Particulate Zinc | Dissolved Zinc
4 | 8023522.577603... | 1665.426815113... | 1272.093733498... | 7550.830771315... | 16592.75839595...
5 | 3617450.521003... | 454.5354824431... | 560.2784469454... | 11742.01011206... | 179927.03617389
6 | 6138237.6229416 | 4236.941552276... | 3741.176353122... | 24602.302999711 | 90546.78307872...
7 | 5889074.921899... | 1445.856454052... | 1993.115422248... | 8962.3382706778 | 38932.78820275...
8 | 7980568.631379... | 3232.838847534... | 1234.649029751... | 17819.68711229... | 12971.03985444...
10 | 10312983.67205... | 852.5606407599... | 629.0713703945... | 5435.802178805... | 19639.35015094...
11 | 8959203.374009... | 475.8130674012... | 325.79117034424 | 2614.390775165... | 2247.387630000...
12 | 8652826.503053... | 1553.173239497... | 3824.299965500... | 8560.292747594... | 24739.93548937...
1748102.735 5924362.583 Meters

5.2.5 Treatment with two trains and mixed PSD (Street sweeping, catchpits, generic treatment, wetland)

The PSD of sediments is dependent on the sediment source. C-CALM has TSS and particulate treatment ratings which vary with grain size for catchpits, street sweeping and settling in ponds and wetlands. C-CALM is therefore able to simulate the treatment of runoff from different sources. C-CALM defines the PSD by apportioning TSS and associated particulates into nine size bands (these are defined in Table 2-2 above). Calculations are made for each size class separately and the results added to give an SMU wide value. For a downstream option in a treatment train, the amount of sediment in each size band is taken from the PSD of sources draining to that option and the output for each band from upstream options.

In this example (Figure 5-9), stormwater in SMU 13 (new industrial, variable PSD) is treated by two separate treatment trains. Runoff from roads and paved surfaces (medium coarse PSD) is treated by street sweeping and catchpits (no inserts). Runoff from roofs (fine PSD) is treated by the generic treatment option option (60% removal of TSS, 45% and 50 % removal for dissolved zinc and copper respectively) and a wetland.

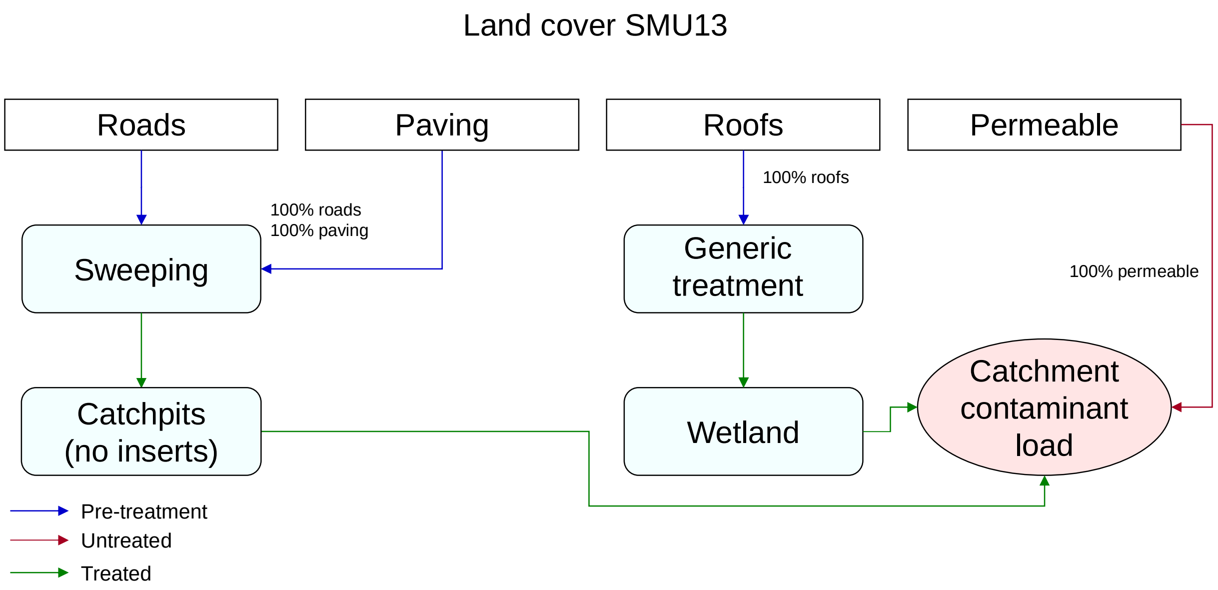


Figure 5-9: Stormwater treatment set-up for SMU 13.

The wetland has the following parameters:

- Land use – industrial
- Imperviousness – 60 % (representing 66% for SMU)
- Slope to gutter – 0.01
- Specific area – 0.5% or 50 m^2/ha
  (i.e., a pond area of around 1550 m^2 serving 31.1 ha of impervious surfaces)
- Hydraulic Efficiency – 8 (excellent)
- Depth/invert level – 1 m
- Weir width – 1 m
- Extended detention – no

This combination gives the following treatment efficiency for TSS and particulates (%) in the C-CALM database:

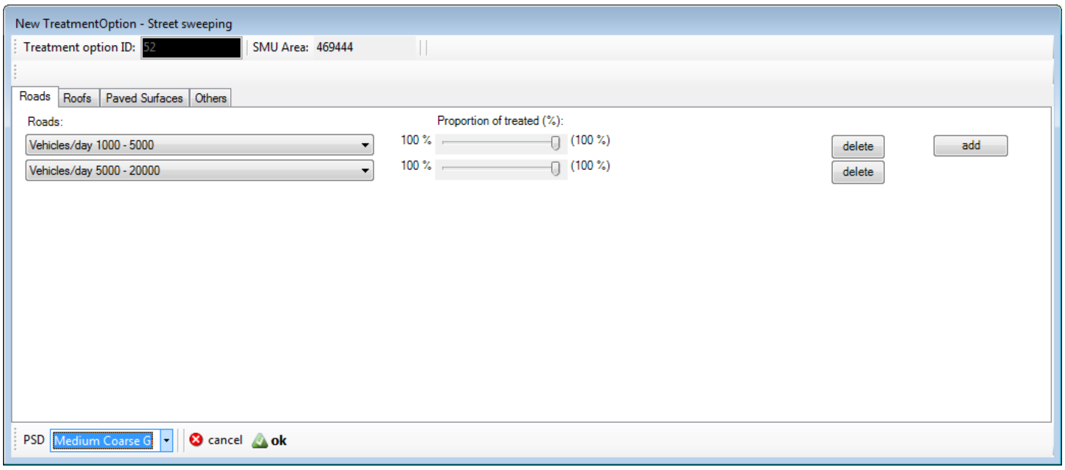
Band1	Band2	Band3	Band4	Band5	Band6	Band7	Band8	Band9
4	5	11	37	84	96	97	97	97

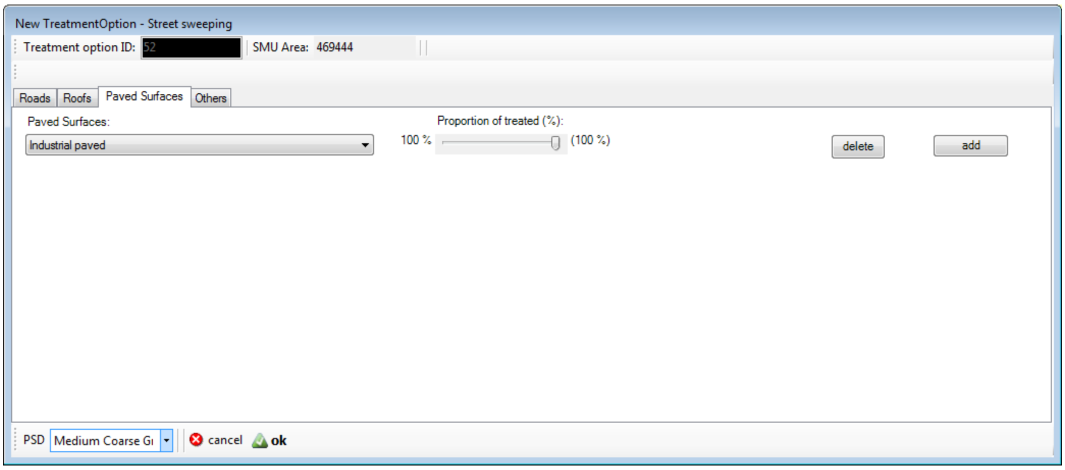
The wetland is assumed to have medium removal of dissolved metals.

1. Close the output table and remove the output layers from the previous run. Highlight the *ccalm_units* shape file in the *TOC* to activate the treatment options and select the SMU to be simulated.

2. Click on the first (upstream) treatment option; in this case the *street sweeping* icon.

3. Click within the SMU boundary to open the *treatment set-up* window for the option and fill as required. Note that the PSD in this example for sediments from roads and paved surfaces is medium coarse.

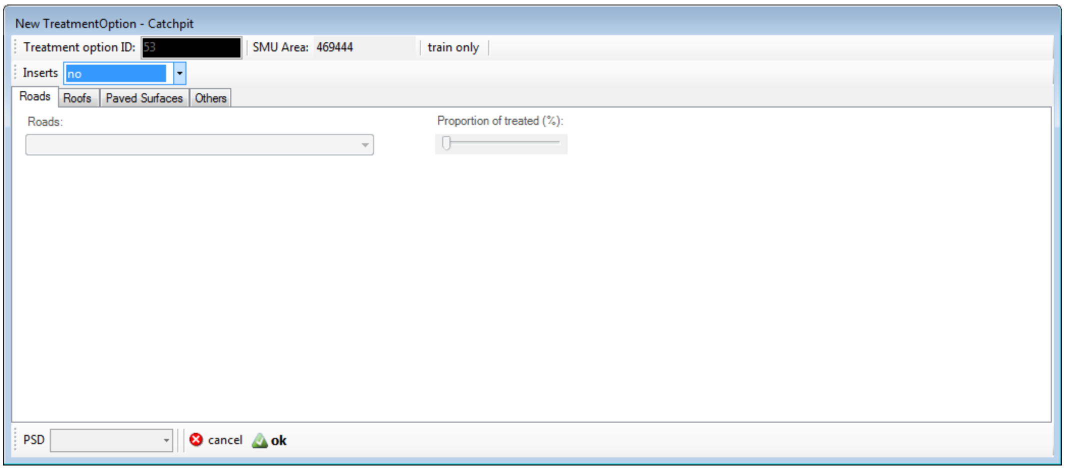




4. Click OK; the symbol for the treatment option will appear in the SMU.

5. Click on second treatment option, in this case the *catchpit* icon.

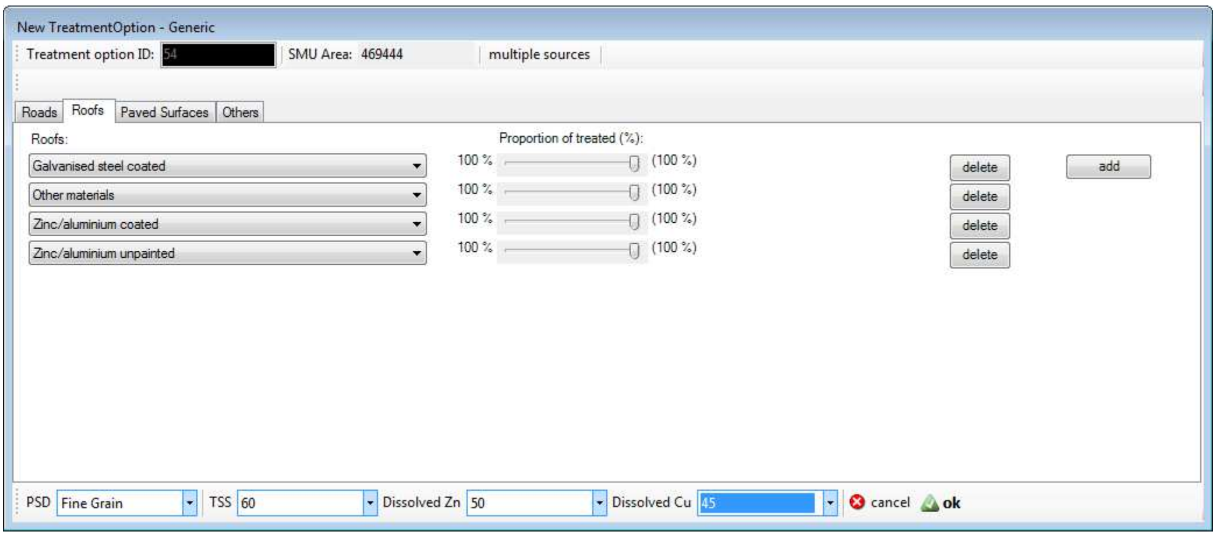
6. Click within the SMU boundary to open the *treatment set-up* window for the option and fill as required. In this example, the catchpit has no insert and receives runoff after sweeping only.



7. Click OK; the symbol for the treatment option will appear in the SMU.

8. Click on third treatment option, in this case the *generic treatment* icon.

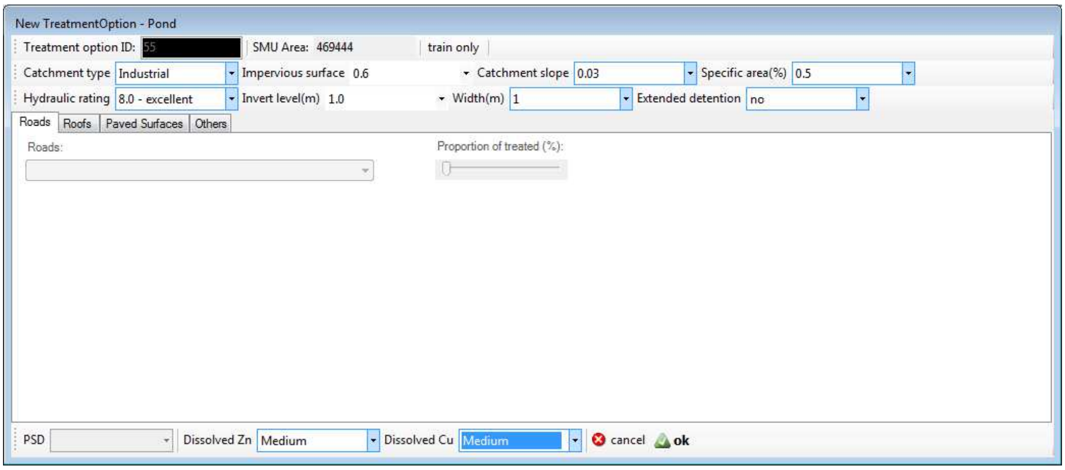
9. Click within the SMU boundary to open the *treatment set-up* window for the option and fill as required. Note that the PSD in this example for sediments from roofs is fine.



10. Click OK; the symbol for the treatment option will appear in the SMU.

11. Click on fourth treatment option, in this case the *wetland* icon

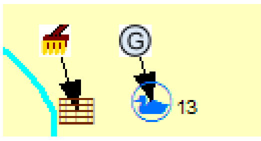
12. Click within the SMU boundary to open the *treatment set-up* window for the option and fill as required.



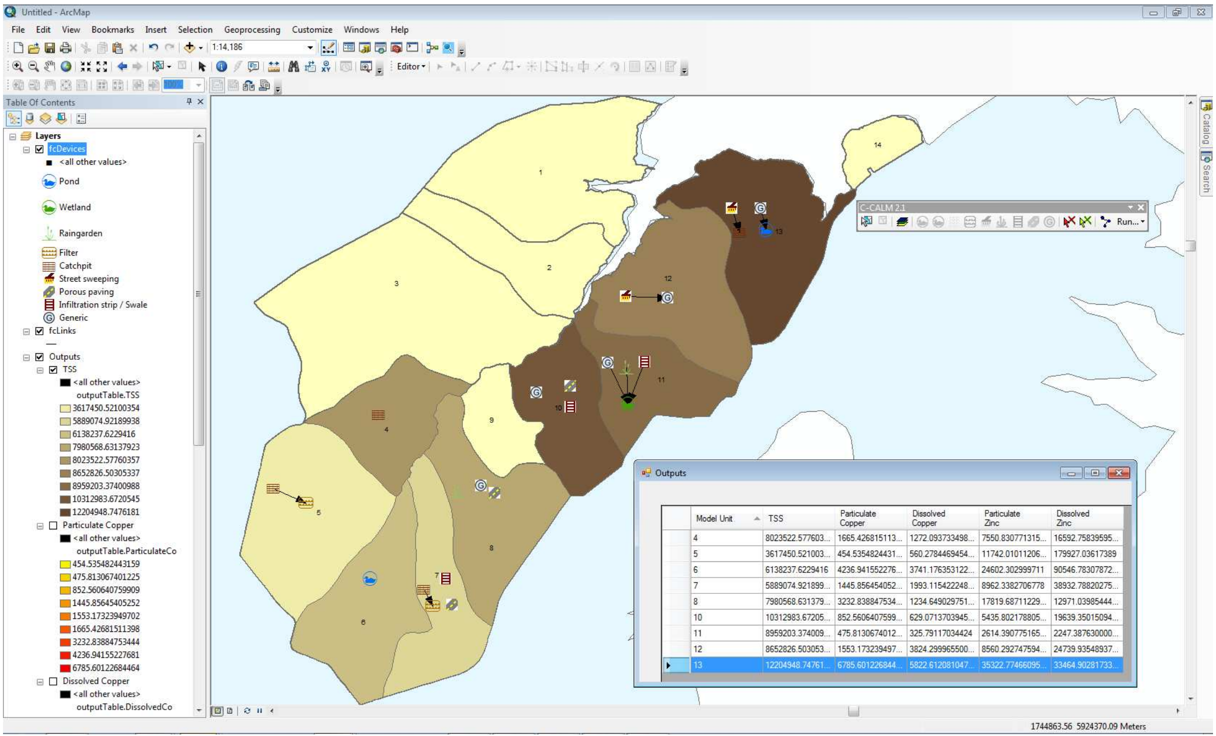
13. Click OK; the symbol for the treatment option will appear in the SMU.

14. Continue to add treatment options until the treatment scenario is complete. Once the treatment options are in place, they can be linked for form trains.

15. Highlight the *fcdevices* shape file in the *TOC* to activate the model tools, click the *link* icon and link the options. In this case sweeping is linked to catch-pits while the generic treatment is linked to the pond.



16. Run C-CALM.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<all other values>
Pond
Wetland
Raingarden
Filter
Catchpit
Street sweeping
Porous paving
Infiltration strip / Swale
Generic
fcLinks
Outputs
TSS
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5889074.92189938
6138237.6229416
7980568.63137923
8023522.57760357
8652826.50305337
8959203.37400988
10312983.6720545
12204948.7476181
Particulate Copper
<all other values>
outputTable.ParticulateCo
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475.813067401225
852.560640759909
1445.85645405252
1553.17323949702
1665.42681511398
3232.83884753444
4236.94155227681
6785.60122684464
Dissolved Copper
<all other values>
outputTable.DissolvedCo
C-CALM 2.1
Run...
Outputs
Model Unit
TSS
Particulate Copper
Dissolved Copper
Particulate Zinc
Dissolved Zinc
4 8023522.577603... 1665.426815113... 1272.093733498... 7550.830771315... 16592.75839595...
5 3617450.521003... 454.5354824431... 560.2784469454... 11742.01011206... 179927.03617389
6 6138237.6229416 4236.941552276... 3741.176353122... 24602.302999711 90546.78307872...
7 5889074.921899... 1445.856454052... 1993.115422248... 8962.3382706778 38932.78820275...
8 7980568.631379... 3232.838847534... 1234.649029751... 17819.68711229... 12971.03985444...
10 10312983.67205... 852.5606407599... 629.0713703945... 5435.802178805... 19639.35015094...
11 8959203.374009... 475.8130674012... 325.79117034424 2614.390775165... 2247.387630000...
12 8652826.503053... 1553.173239497... 3824.299965500... 8560.292747594... 24739.93548937...
13 12204948.74761... 6785.601226844... 5822.612081047... 35322.77466095... 33464.90281733...
1744863.56 5924370.09 Meters

5.2.6 Treatment trains with multiple links (street sweeping, porous paving, swales, generic treatment) – four in a row

C-CALM is not restricted in the number of treatment options possible in a train. In this example (Figure 5-10) runoff from SMU 3 (high density) is treated in a train with four linked options in series. All of the roads are swept, and roads and paved surfaces are porous. Runoff from the roads and paved surfaces drains via swales to generic treatment. The porous paving has medium treatment for all contaminants while swales have low levels of treatment and the generic treatment has 75% TSS and particulate removal and 60% removal of dissolved metals. Runoff from half of the roofs is also treated in the swales and raingardens.

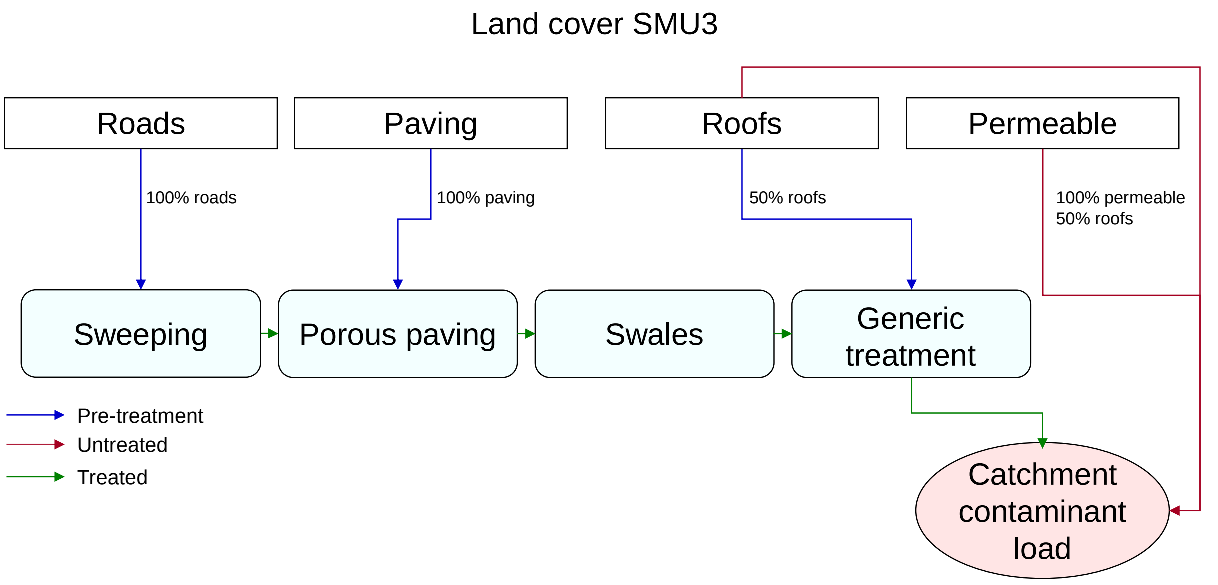
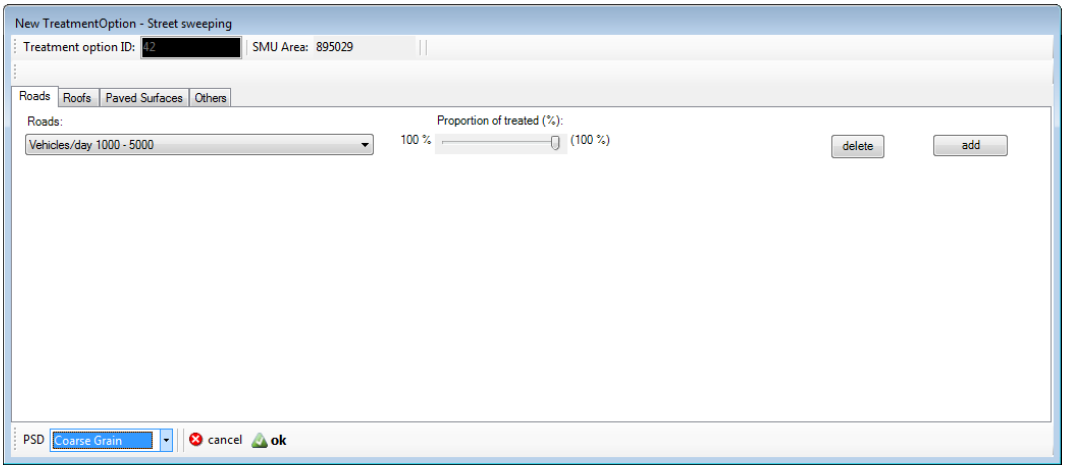


Figure 5-10:Stormwater treatment set-up for SMU 3.

1. Close the output table and remove the output layers from the previous run. Highlight the *ccalm_units* shape file in the *TOC* to activate the treatment options and select the SMU to be simulated.

2. Click on the first (upstream) treatment option, in this case the *street sweeping* icon.

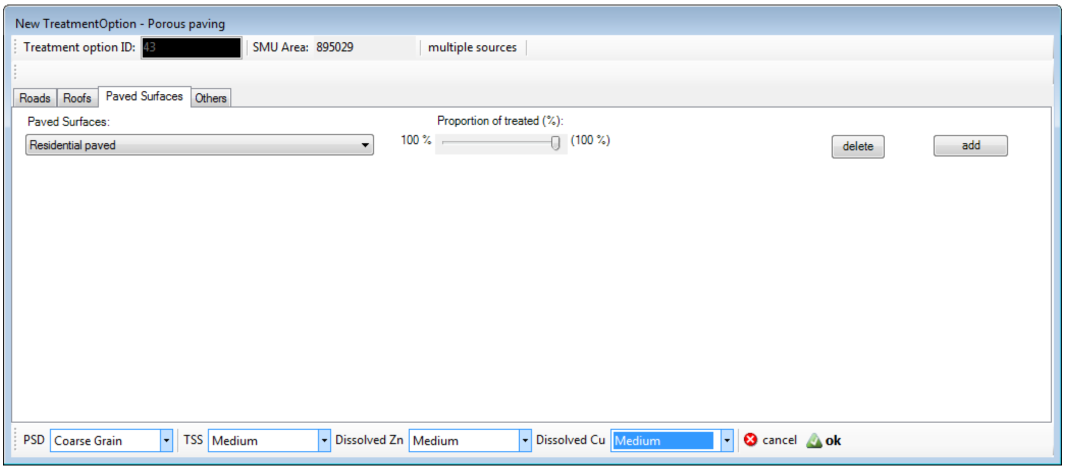
3. Click within the SMU boundary to open the *treatment set-up* window for the option and fill as required.



4. Click OK; the symbol for the treatment option will appear in the SMU.

5. Click on second treatment option, in this case the *porous paving* icon.

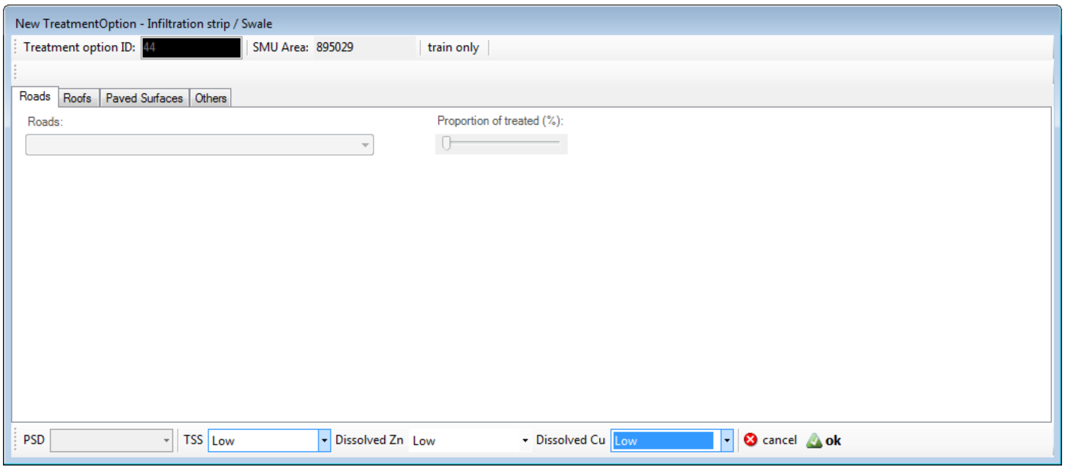
6. Click within the SMU boundary to open the *treatment set-up* window for the option and fill as required.



7. Click OK; the symbol for the treatment option will appear in the SMU.

8. Click on third treatment option, in this case the *swales / infiltration strip* icon.

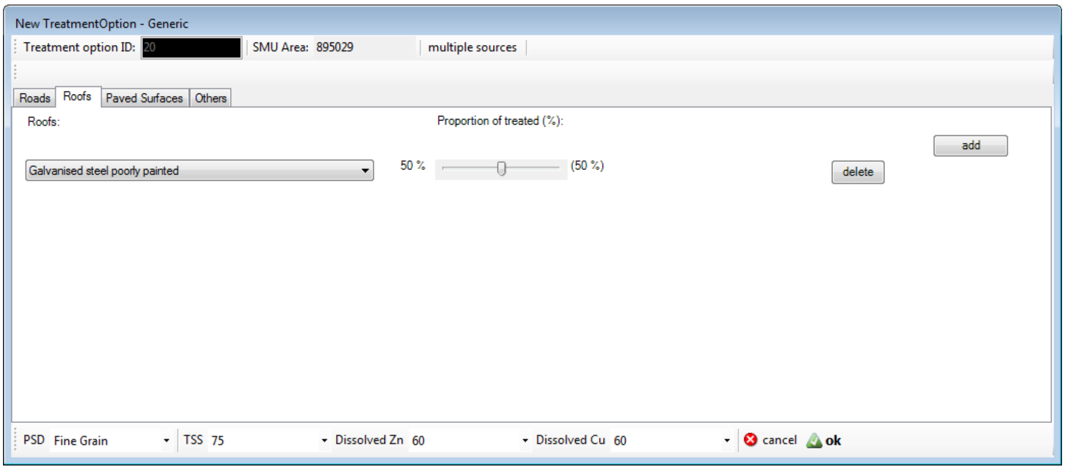
9. Click within the SMU boundary to open the *treatment set-up* window for the option and fill as required. IN this scenario, the swales receive inflow from the porous paving, so the option is switched from *multiple sources* to *train only*.



10. Click OK, the symbol for the treatment option will appear in the SMU.

11. Click on fourth treatment option, in this case the *generic treatment* icon.

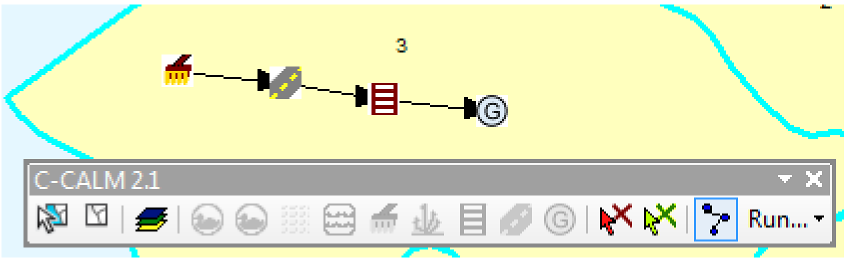
12. Click within the SMU boundary to open the *treatment set-up* window for the option and fill as required. The generic treatment in this example takes treated water from the swales as well as half of roof runoff from poorly painted galvanised steel roofing. TSS from the roofs is assumed to be fine grained.



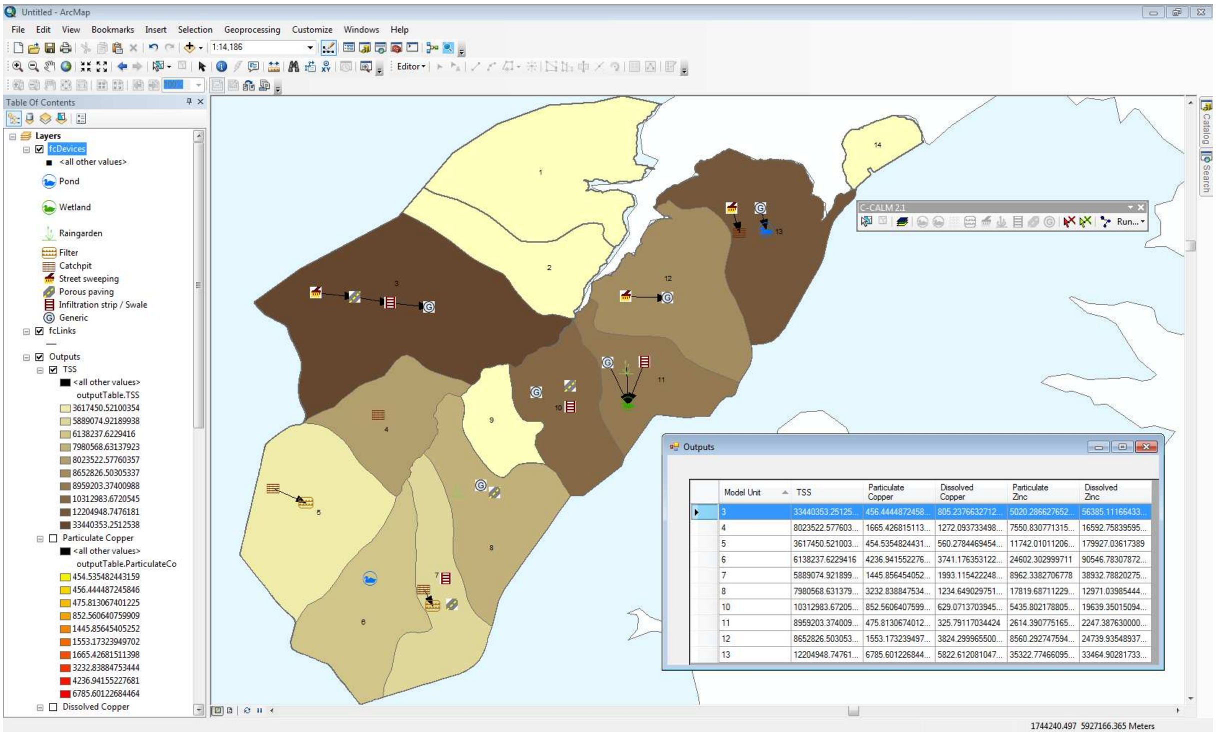
13. Click OK; the symbol for the treatment option will appear in the SMU.

14. Continue to add treatment options until the treatment scenario is complete. Once the treatment options are in place, they can be linked for form trains.

15. Highlight the *fcdevices* shape file in the *TOC* to activate the model tools, and link the devices. In this case the street sweeping, porous paving, swales and the generic treatment symbols are linked in series.



16. Run C-CALM.



5.2.7 Complex treatment train with mixed PSD (catchpits with inserts, proprietary filters, wetland)

In this example (Figure 5-11), stormwater in SMU 2 (high density residential, fine and medium PSD) is treated with a combination of traditional and WSUD treatment options culminating in a constructed wetland. Runoff from roads and paving (medium PSD) is pre-treated with catchpits which drain to filters and then to the wetland. Runoff from 25% of roofs (fine PSD) is a raingarden before draining to the wetland.

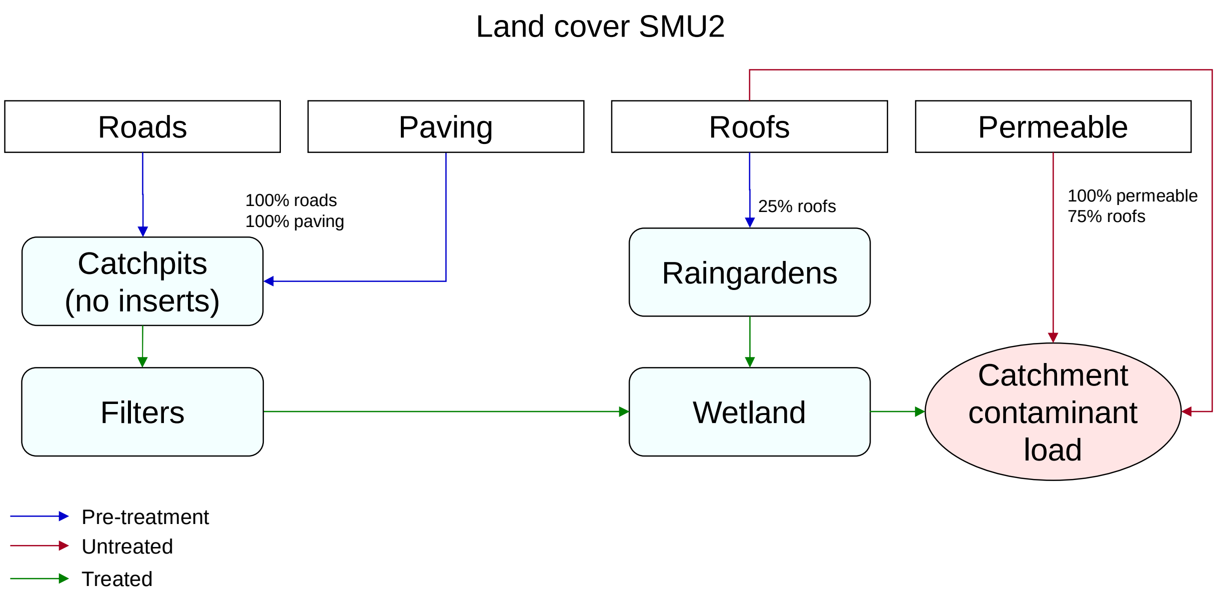


Figure 5-11:Stormwater treatment set-up for SMU 12.

The raingardens have the following design parameters:

- Land use – residential
- Slope to gutter – 0.005
- Specific area – 1% or 10 m^2/1000 m^2
- Media depth – 0.5 m
- Deep percolation – 0 (i.e., lined with no percolation to groundwater)
- By-pass – yes
- Median media grain size – 1 mm

The removal efficiency of TSS/particulates for a raingarden with these characteristics in the C-CALM performance rules is 38% (i.e., a high proportion of bypass). The removal efficiency for the dissolved metals is assumed to be low.

The wetland is assumed to have medium removal or dissolved metals has the following design parameters:

- Land use – residential
- Imperviousness – 60 % (representing 57% for SMU
- Slope to gutter – 0.05
- Specific area – 1.5% or 50 m^2/ha
  (i.e., a pond area of around 1580 m^2 serving 10 ha of impervious surfaces)
- Hydraulic Efficiency – 8 (excellent)
- Depth/invert level – 1.5 m
- Weir width – 2 m
- Extended detention – yes

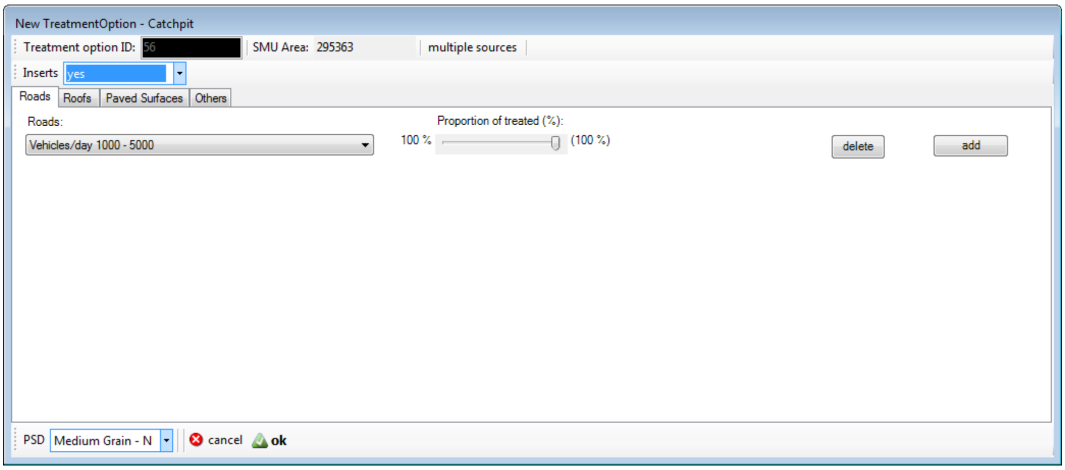
This combination gives the following treatment efficiency for TSS and particulates (%) in the C-CALM database:

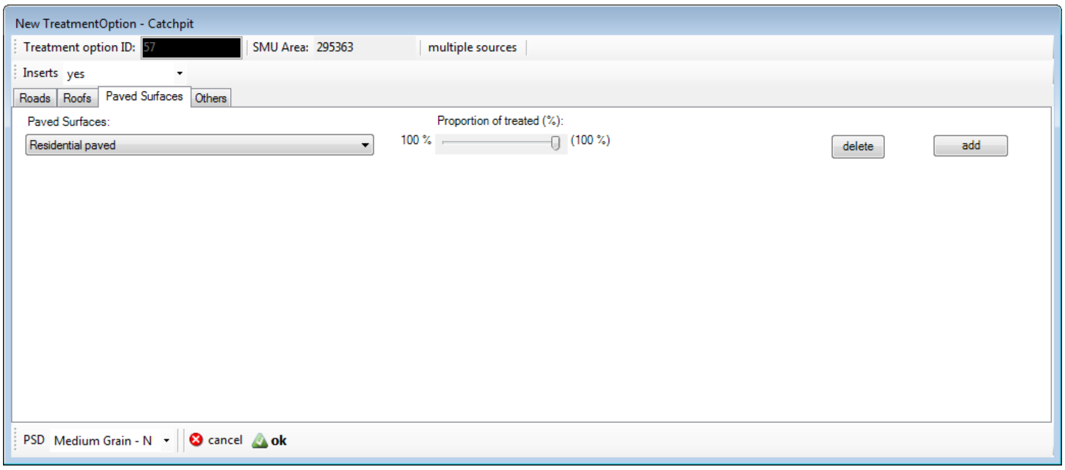
Band1	Band2	Band3	Band4	Band5	Band6	Band7	Band8	Band9
20	22	36	75	98	100	100	100	100

1. Close the output table and remove the output layers from the previous run. Highlight the *ccalm_units* shape file in the *TOC* to activate the treatment options and select the SMU to be simulated.

2. Click on the first (upstream) treatment option, in this case the *catchpits* icon.

3. Click within the SMU boundary to open the *treatment set-up* window for the option and fill as required. Note that the PSD in this example for sediments from roads and paved surfaces is medium grain.

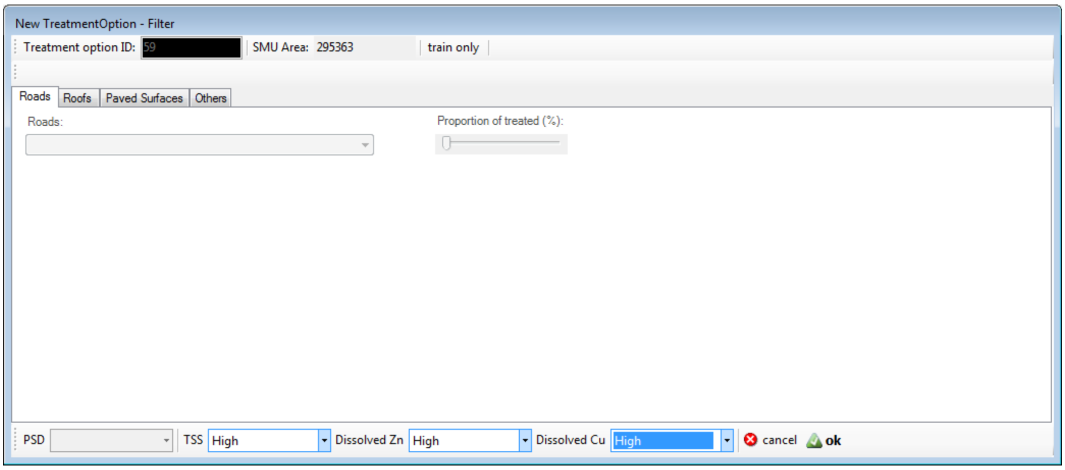




4. Click OK; the symbol for the treatment option will appear in the SMU.

5. Click on second treatment option, in this case the *filter* icon.

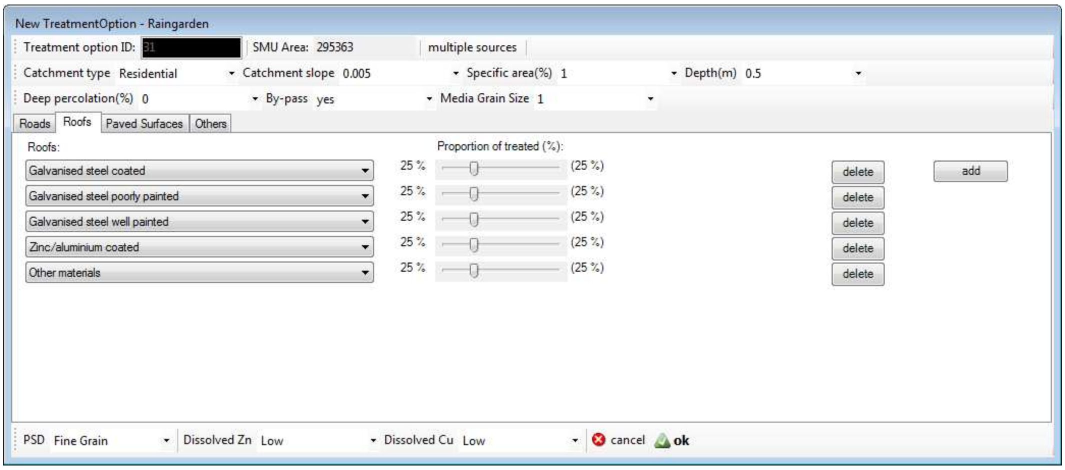
6. Click within the SMU boundary to open the *treatment set-up* window for the option and fill as required. In this example, the filter is set to *train only* as all the inflow is pre-treated by the catchpit inserts. The PSD of the sediments reaching the filter has been modified from the original medium grain PSD to reflect the preferential removal of coarse-grained sediments by the catchpit inserts.



7. Click OK; the symbol for the treatment option will appear in the SMU.

8. Click on third treatment option, in this case the *raingardens* icon.

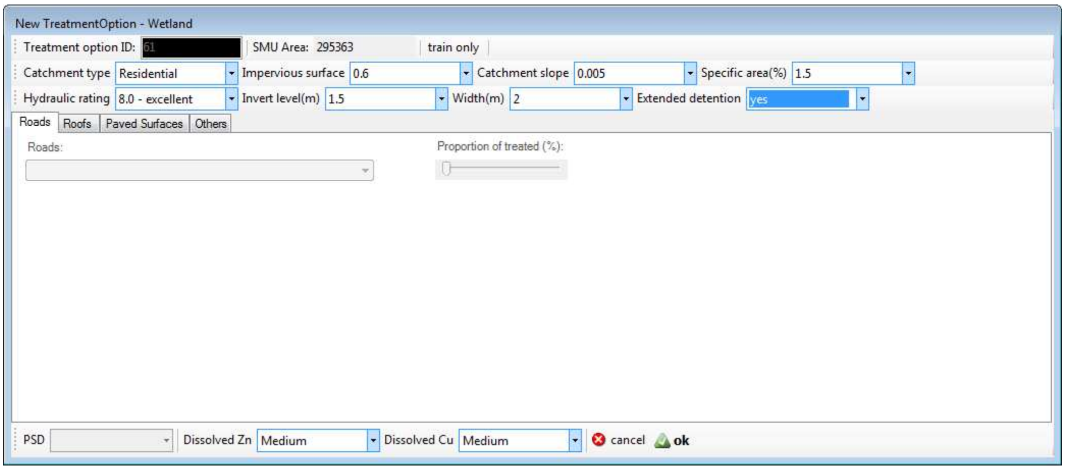
9. Click within the SMU boundary to open the *treatment set-up* window for the option and fill as required. Note that the PSD in this example for sediments from roofs is fine.



10. Click OK; the symbol for the treatment option will appear in the SMU.

11. Click on fourth treatment option, in this case the *wetland* icon.

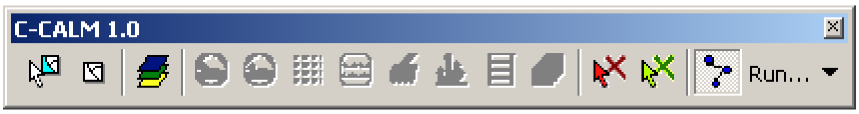
12. Click within the SMU boundary to open the *treatment set-up* window for the option and fill as required. The proportion of sediment in each size class reaching the wetland depends on the original PSD from the different sources (i.e., medium PSD from roads and paved surfaces and fine PSD from roofs) and the level of treatment for each size class in the up-stream treatment options (i.e., catchpits and filters, and raingardens respectively).



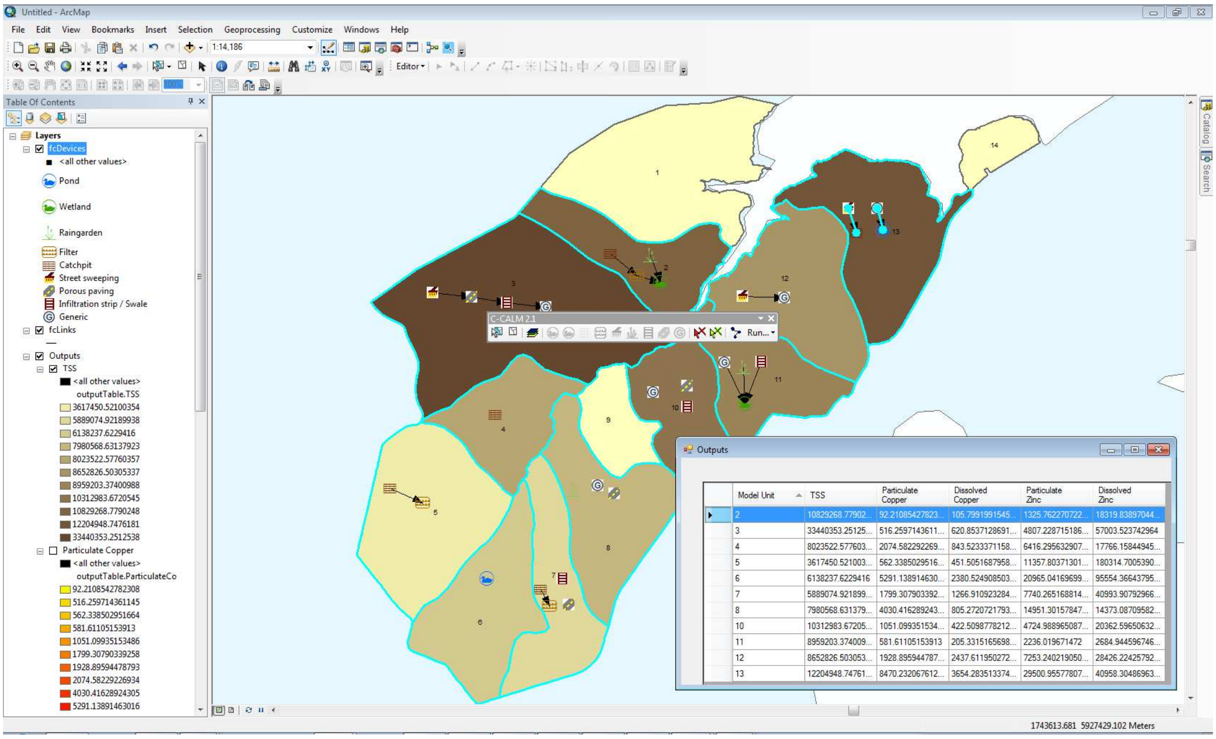
13. Click OK; the symbol for the treatment option will appear in the SMU.

14. Continue to add treatment options until the treatment scenario is complete. Once the treatment options are in place, they can be linked for form trains.

15. Highlight the *fcdevices* shape file in the *TOC* to activate the model tools, click the *link* icon and link the options. In this case the catchpits are linked to filters which are further linked to the wetland. Raingardens are also linked to the wetland.



16. Run C-CALM by clicking on the *Run* drop down menu and selecting *build and run* (note the *fcdevices* shape file in the *TOC* should already be active and the links icon clicked as part of the linking process).


Untitled - ArcMap
File
Edit
View
Bookmarks
Insert
Selection
Geoprocessing
Customize
Windows
Help
Table Of Contents
Layers
fcDevices
<all other values>
Pond
Wetland
Raingarden
Filter
Catchpit
Street sweeping
Porous paving
Infiltration strip / Swale
Generic
fcLinks
Outputs
TSS
outputTable.TSS
Particulate Copper
outputTable.ParticulateCo
C-CALM 2.1
Outputs
Model Unit
TSS
Particulate Copper
Dissolved Copper
Particulate Zinc
Dissolved Zinc
2 10829268.77902... 92.21085427823... 105.7991991545... 1325.762270722... 18319.83897044...
3 33440353.25125... 516.2597143611... 620.8537128691... 4807.228715186... 57003.523742964
4 8023522.577603... 2074.582292269... 843.5233371158... 6416.295632907... 17766.15844945...
5 3617450.521003... 562.3385029516... 451.5051687958... 11357.80371301... 180314.7005390...
6 6138237.6229416 5291.138914630... 2380.524908503... 20965.04169699... 95554.36643795...
7 5889074.921899... 1799.307903392... 1266.910923284... 7740.265168814... 40993.90792966...
8 7980568.631379... 4030.416289243... 805.2720721793... 14951.30157847... 14373.08709582...
10 10312983.67205... 1051.099351534... 422.5098778212... 4724.988965087... 20362.59650632...
11 8959203.374009... 581.61105153913 205.3315165698... 2236.019671472 2684.944596746...
12 8652826.503053... 1928.895944787... 2437.611950272... 7253.240219050... 28426.22425792...
13 12204948.74761... 8470.232067612... 3654.283513374... 29500.95577807... 40958.30486963...
1743613.681 5927429.102 Meters

5.2.8 Complex multiple trains

C-CALM can simulate complex treatment scenarios within a SMU using combinations of trains and split land use proportions. This means that SMUs with several examples of a treatment options albeit with different levels of treatment (e.g., due to different contaminant sources or different device dimensions, filter media or design) can be simulated. In this example (Figure 5-12), runoff from SMU 9 (commercial, medium coarse PSD) is treated in two treatment trains.

The configuration for the SMU treatment is shown over the page, refer to the previous examples on how to enter treatment options. In the first train, 20% of roads and paving are drained via catchpits (no inserts) to raingardens and then a pond. A further 20% of the runoff from roads and paving drains via catchpits (no inserts) to proprietary filters, and then to the same pond. In the second train, 30% of roads and paving drain via catchpits (with inserts) to a second pond. A further 10% of roads and paving are porous and are drained via swales (with inserts) to the second pond. The swales also treat runoff from 10% of the roofs. A further 30% of roof runoff drains directly to the second pond.

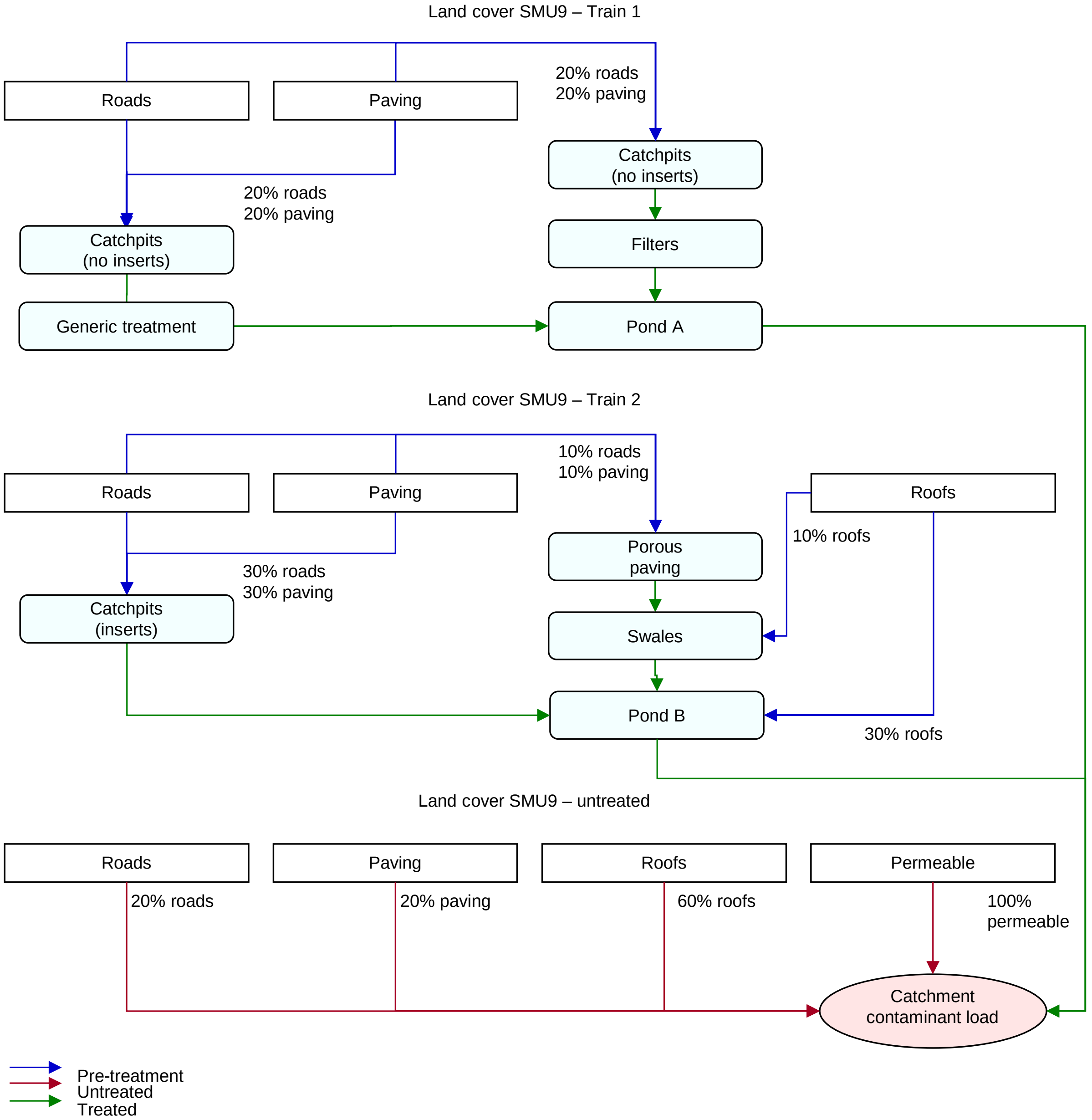


Figure 5-12:Stormwater treatment set-up for SMU 9.

Train 1

The configuration for train 1 (Figure 5-13) is as follows:

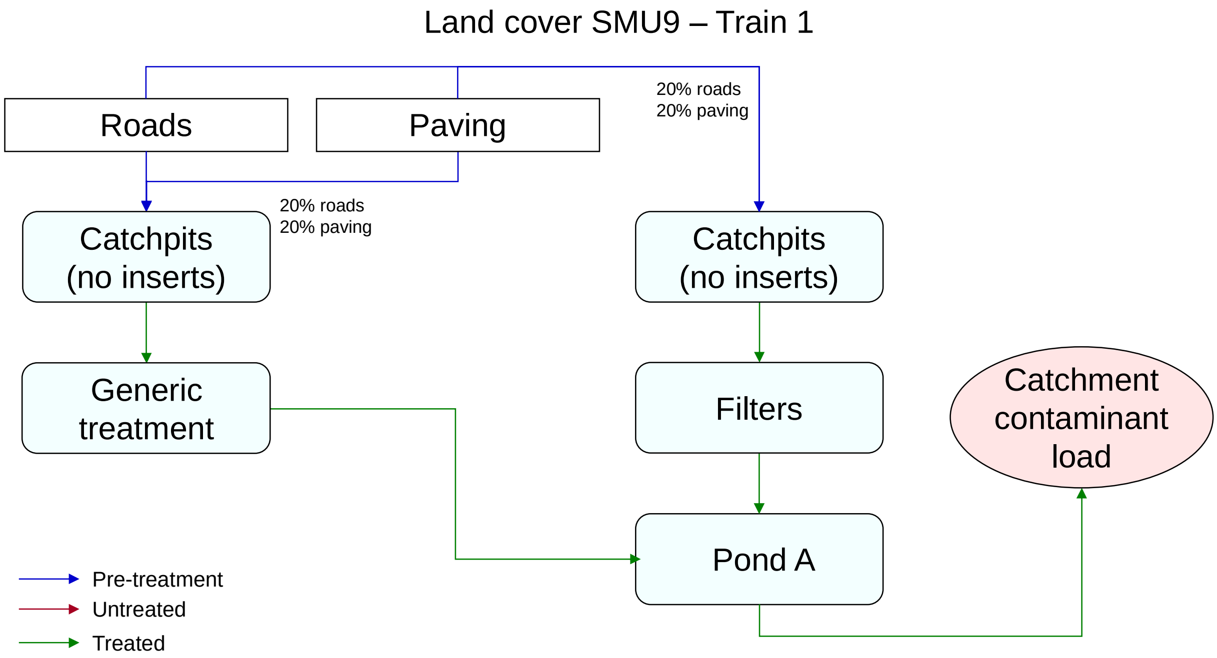
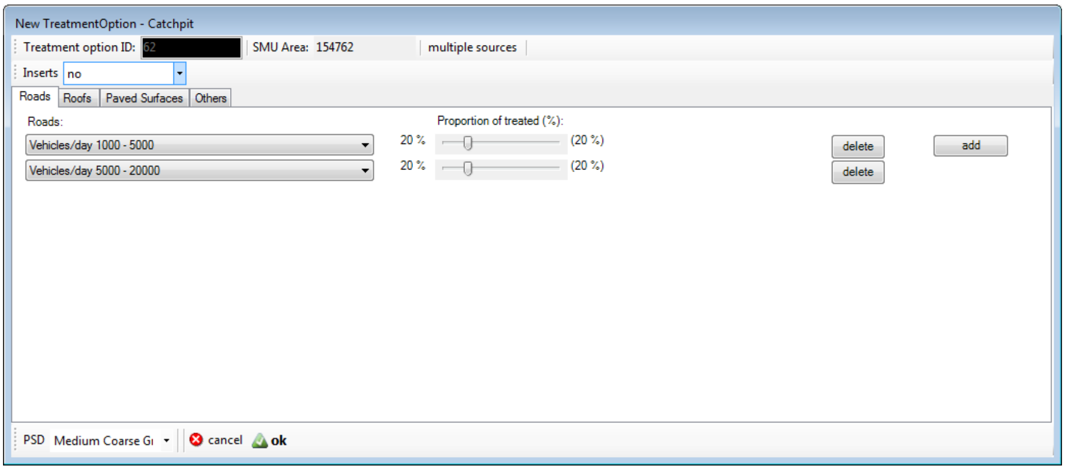
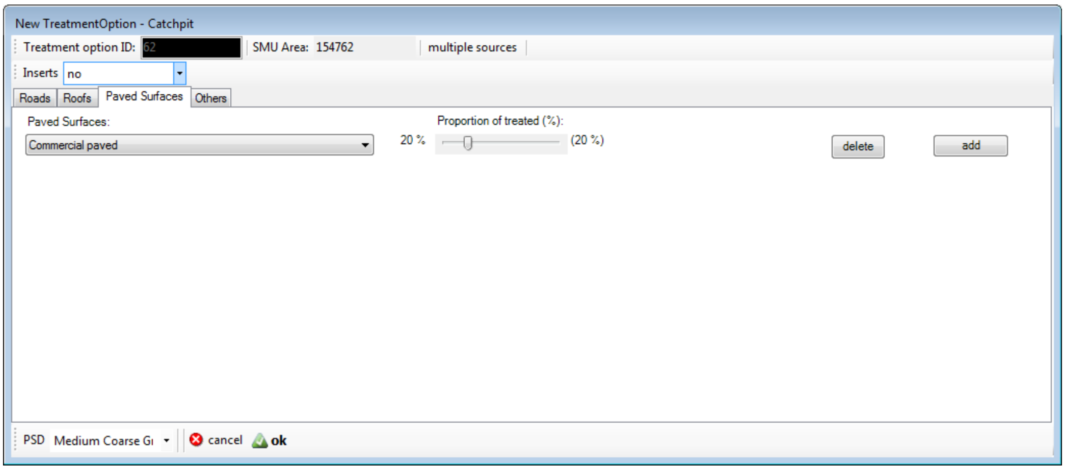


Figure 5-13:Stormwater treatment set-up for SMU 9, Train 1.

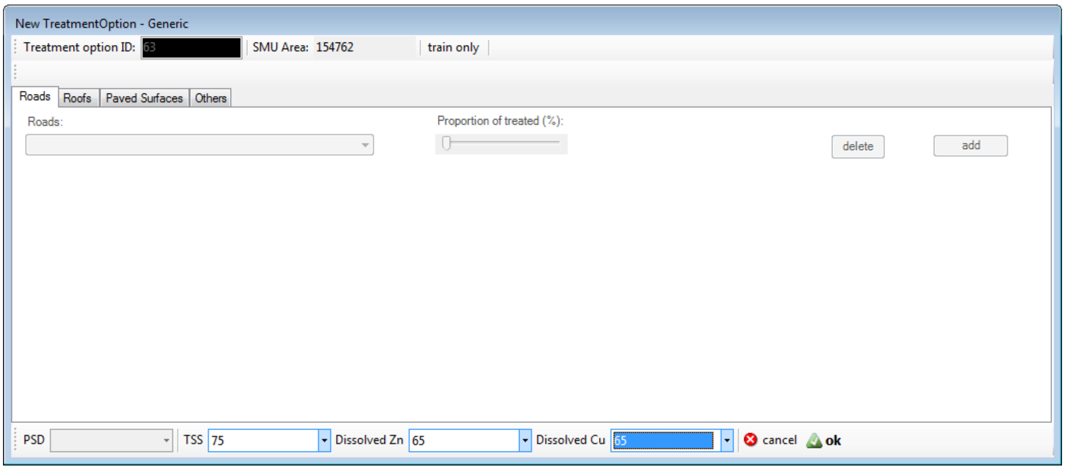
Catchpits to generic treatment

Catchpits (no inserts) treat 20% of roads and 20% of paving and drain to the generic treatment option.



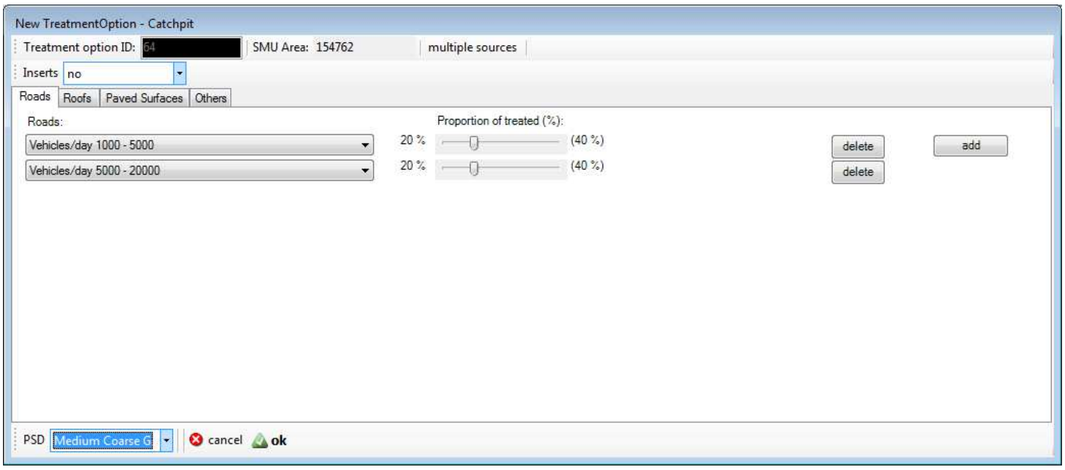


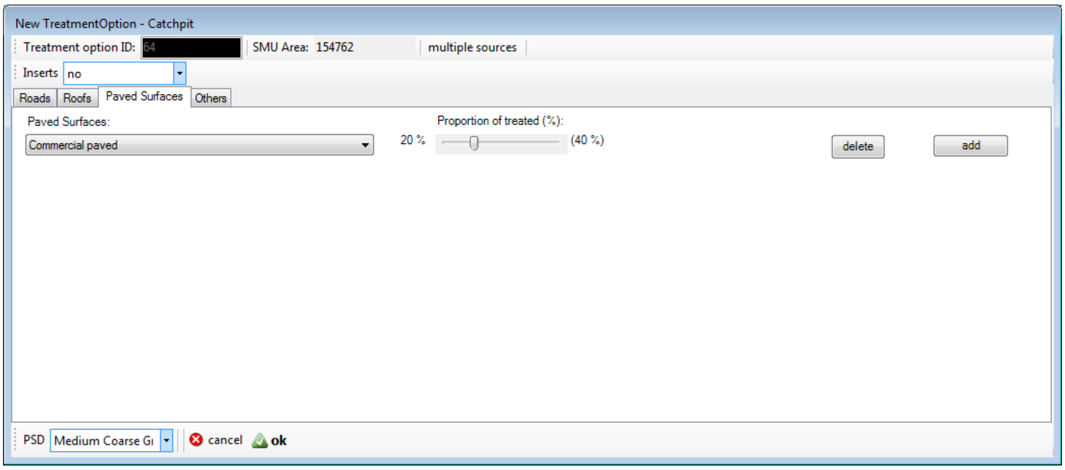
The generic treatment option is set to train only and provides 75% removal of TSS and 65% removal of dissolved metals.



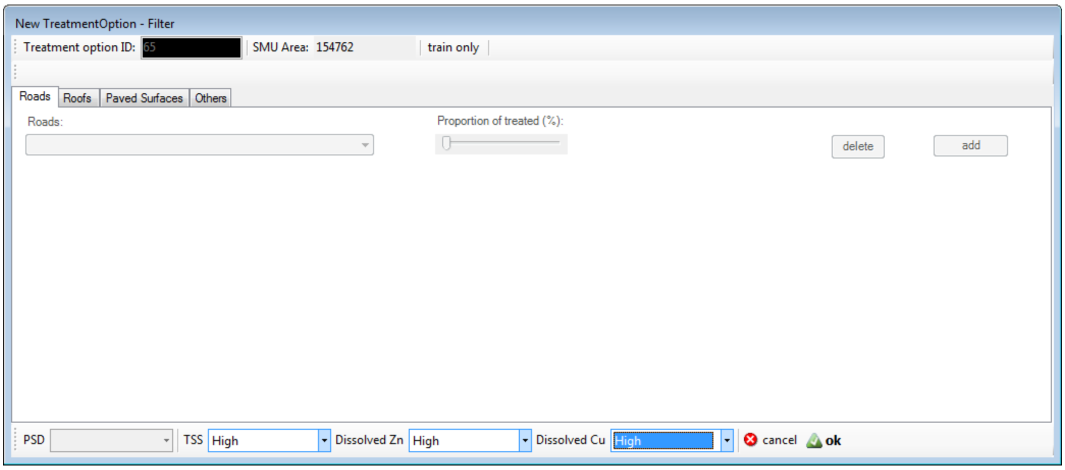
Catchpits to Filters

Catchpits (no inserts) treat a further 20% of roads and 20% of paving and drain to filters



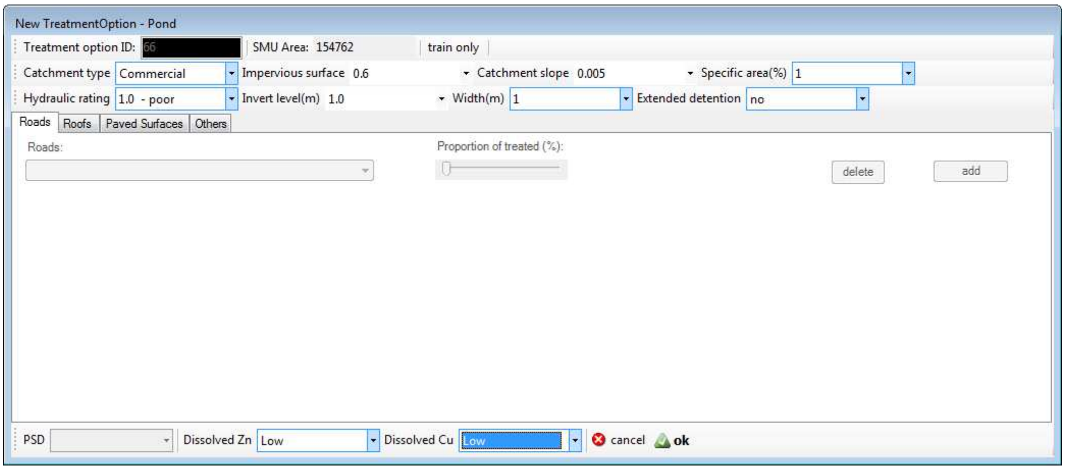


Filters are set to train only and provide high treatment of TSS and dissolved metals.



Pond A

Pond A receives inflow from the generic treatment option and filters. The pond is set to train only and provides low treatment of dissolved metals.



Pond settings:

- Land use – commercial
- Imperviousness – 60 %
- Slope to gutter – 0.005
- Specific area – 1% or 100 m^2/ha
- Hydraulic Efficiency – 1 (poor)
- Depth/invert level – 1 m
- Weir width – 1 m
- Extended detention - no

This combination gives the following treatment efficiency (%) in the C-CALM database:

Band1	Band2	Band3	Band4	Band5	Band6	Band7	Band8	Band9
8	9	20	50	83	95	98	99	99

Train 2

The configuration for the second treatment train (Figure 5-14) is as follows:

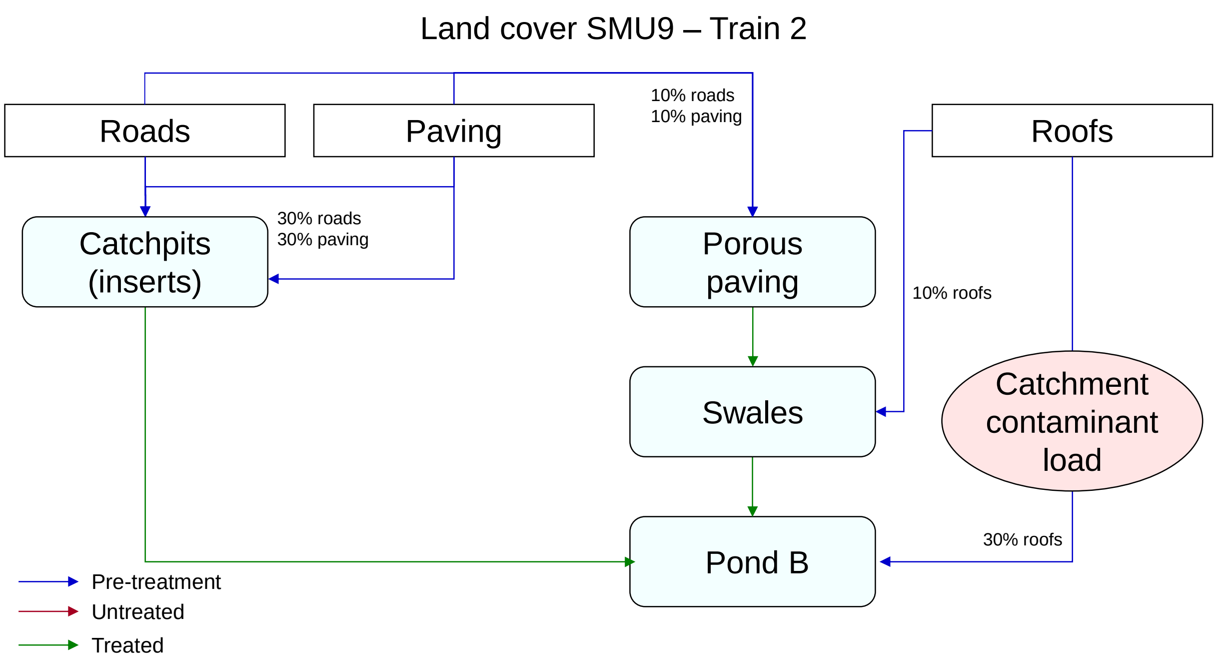
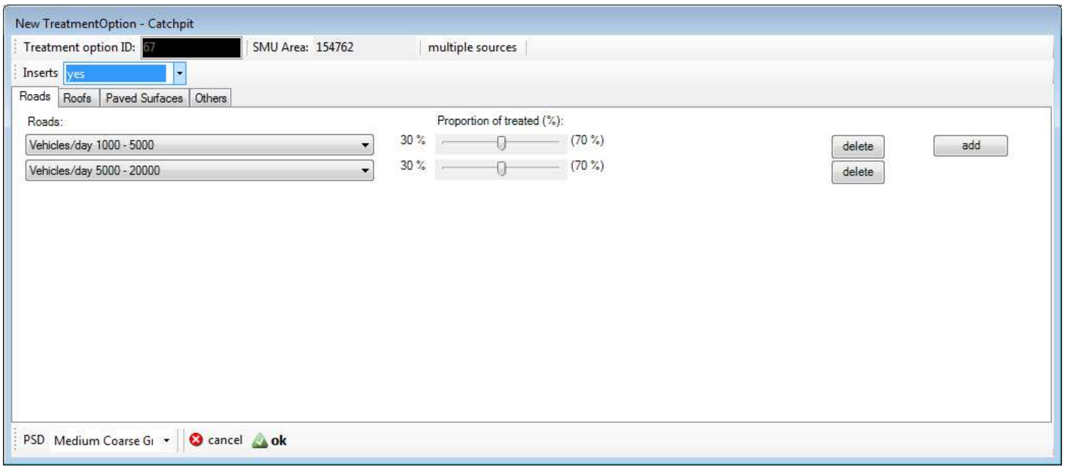
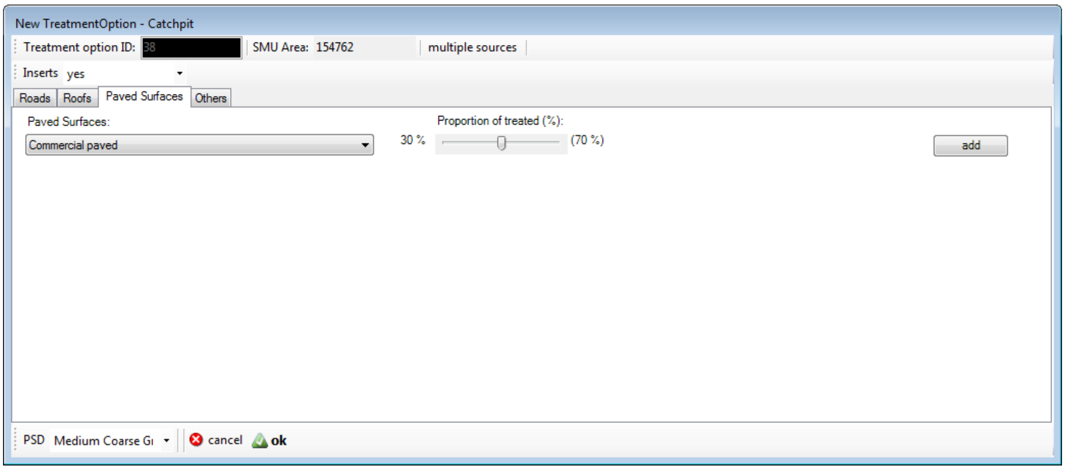


Figure 5-14:Stormwater treatment set-up for SMU 9, Train 2.

Catchpits with inserts

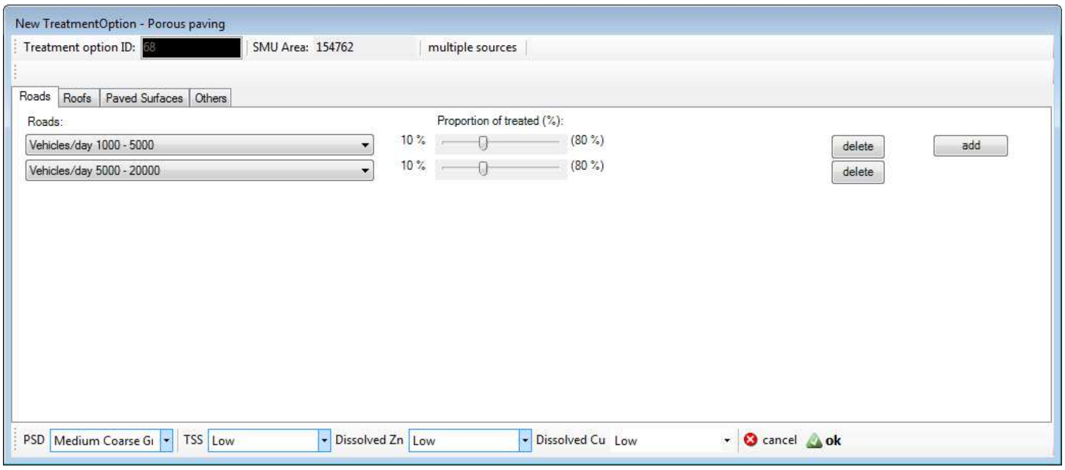
Catchpits with inserts treat 30% of roads and 30% of paving, the treated runoff drains directly to Pond B.

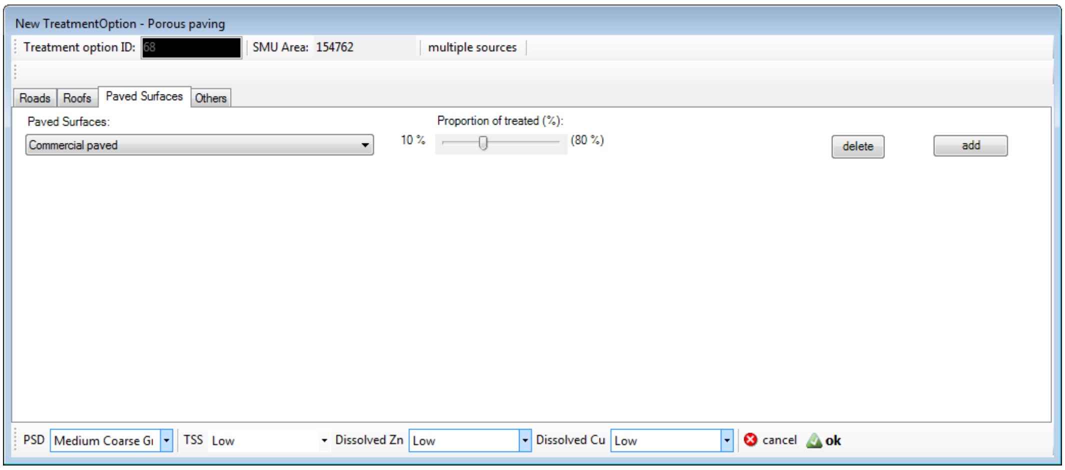




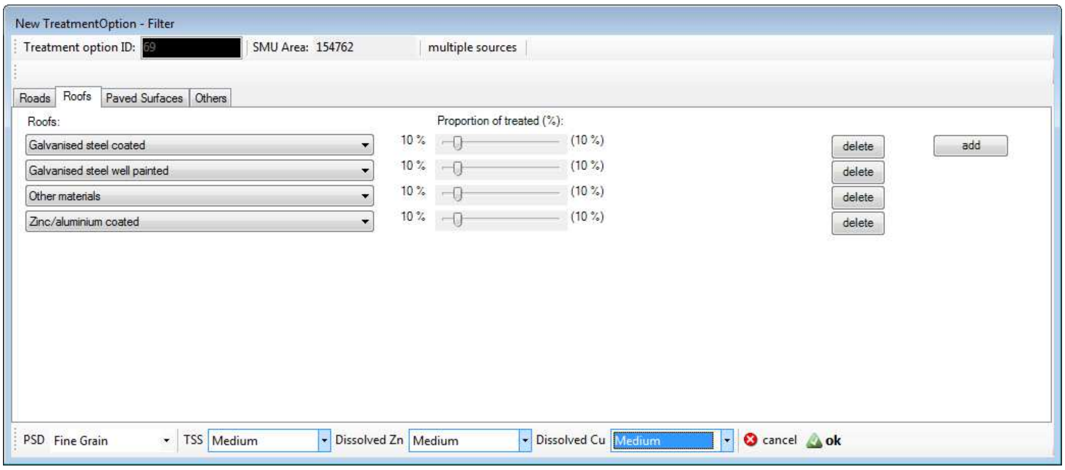
Porous paving to filters

Porous paving treats 10% of roads and 10% of paving and provides low removal of TSS and dissolved metals. The outflow is further treated in filters.



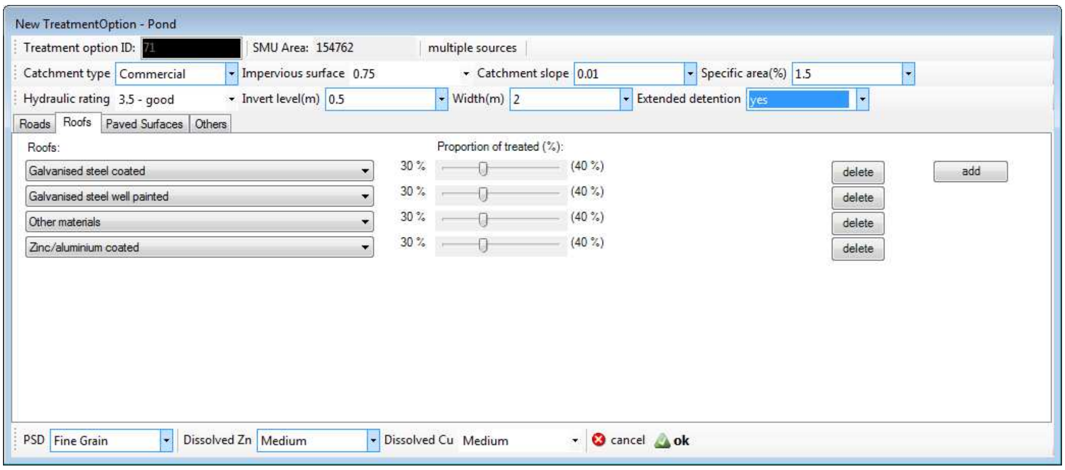


Filters treat runoff from the porous paving and 10% of roof runoff (fine PSD). They provide medium treatment of TSS and dissolved metals. The treated runoff flows to pond B.



Pond B

Pond B treats water from the filters and catchpits (with inserts) as well as 30% of roof runoff (fine PSD). Pond B provides medium treatment of dissolved metals.



Pond settings:

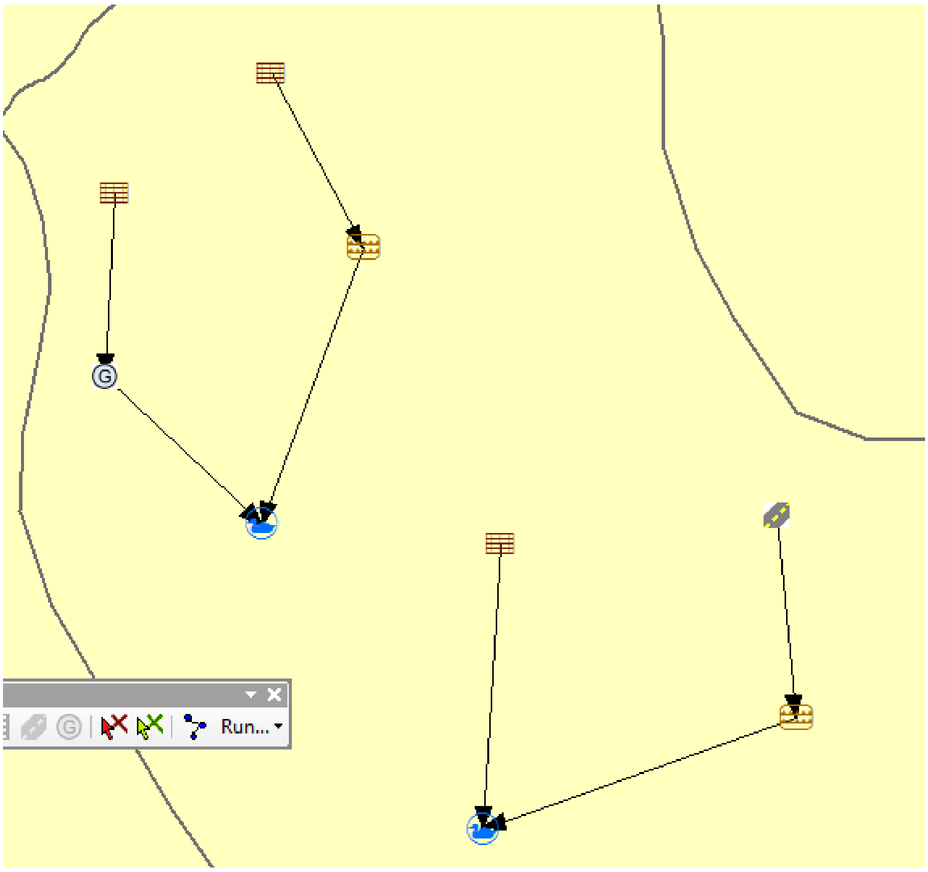
- Land use – commercial
- Imperviousness – 75 %
- Slope to gutter – 0.015
- Specific area – 1.5% or 150 m^2/ha
- Hydraulic Efficiency – 3.5 (good)
- Depth/invert level – 0.5 m
- Weir width – 2 m
- Extended detention - yes

This combination gives the following treatment efficiency (%) in the C-CALM database:

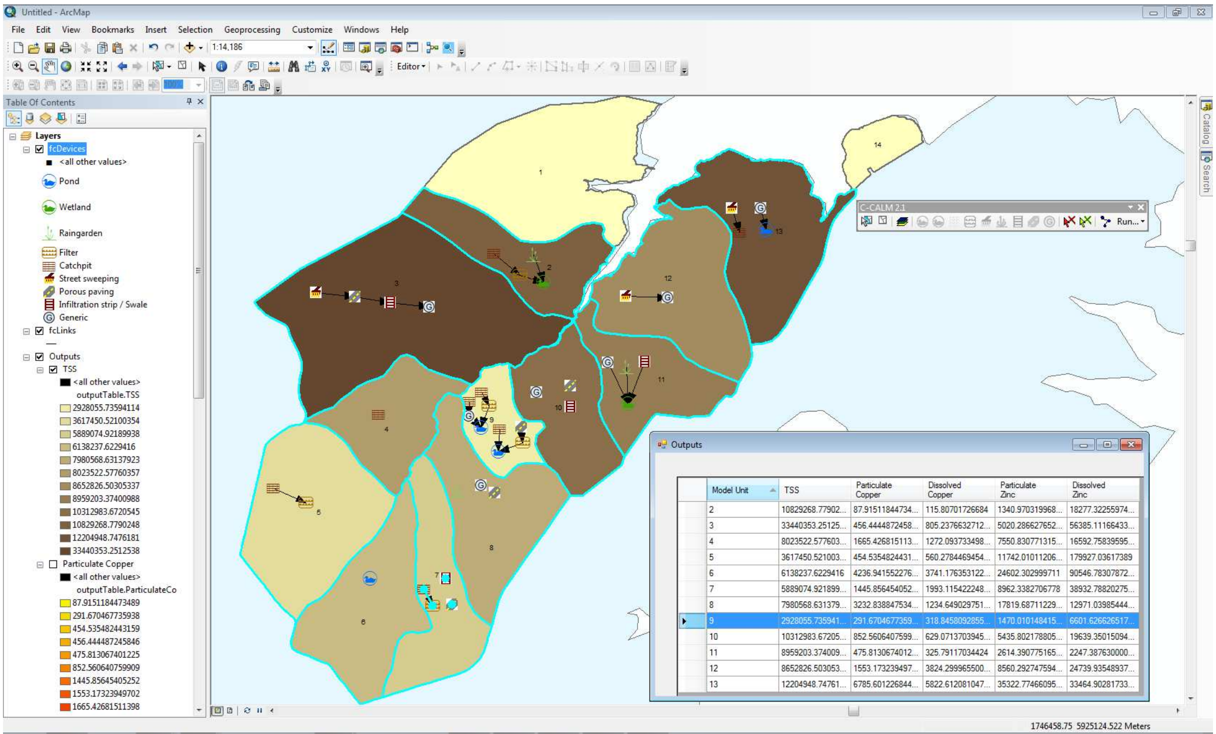
Band1	Band2	Band3	Band4	Band5	Band6	Band7	Band8	Band9
8	10	23	62	95	99	99	99	99

Train links

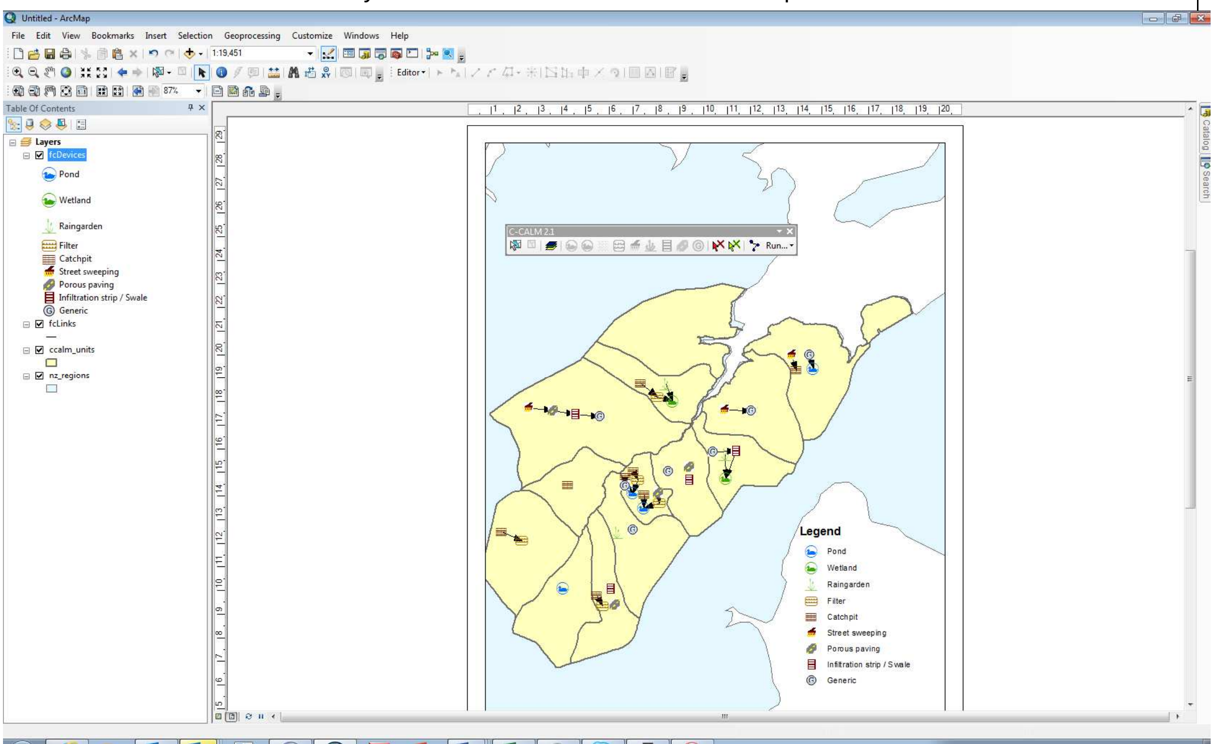
The links between the treatment options in the two trains are as follows:



Simulation results



TROUBLESHOOTING: I am in Layout view and cannot add a treatment option.



While C-CALM will allow you to edit treatment options and run the model in Layout view, you cannot add new treatments or links. Returning to data view will restore full model function.

5.3 Comparing results

The examples above have shown the way in which C-CALM can be used to simulate stormwater treatment options with a range of complexity, from single treatment options to complex trains. Table 5-1 compares the results obtained with the treatment options above with those given in Section 4.4 for the catchment without treatment.

Figure 5-15 uses this data to compare pre- and post-treatment total copper for each SMU. The chart was prepared in Excel using data exported from the C-CALM output tables. The outputs can also be analysed and imported back into ArcMAP for display. In Figure 5-16, the change in simulated TSS yields (loads/area; kg/ha/year) are compared for the catchment. Yields are useful in identifying hot-spots as the loads are normalised for SMU area.

It is interesting to note that the removal efficiencies for particulate metals is greater than for TSS even though sediment and particulates are removed in each of the treatment options with the same removal efficiency. The reason for this apparent anomaly is that the sediments from impervious surfaces (i.e., urban grassland which represents gardens and parks, and have the greatest sediment yield of the urban surface covers), are not treated in the treatment scenarios.

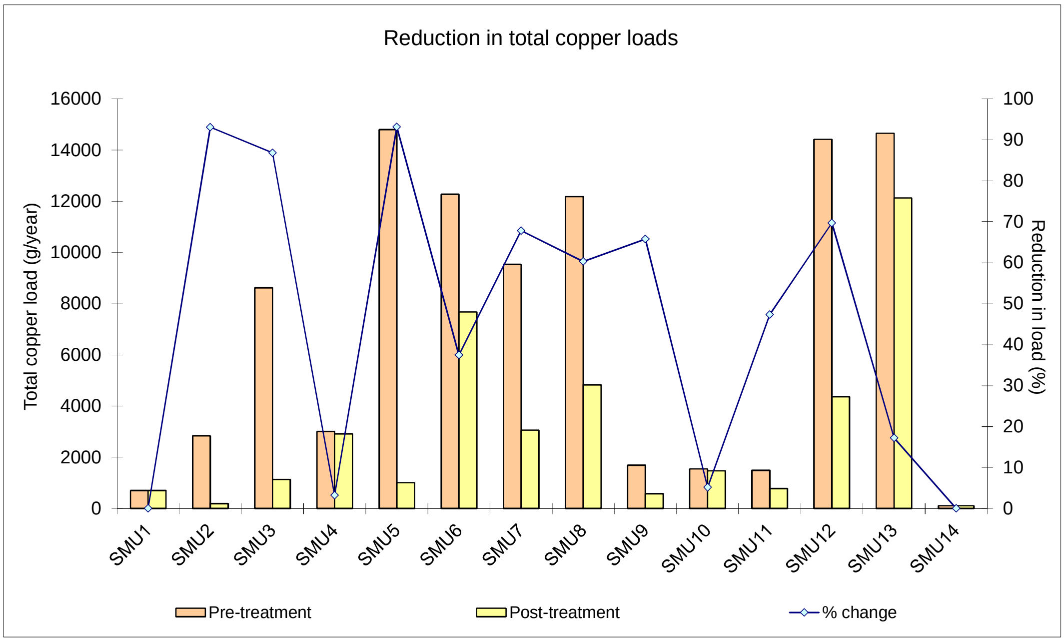


Figure 5-15:Comparison of total copper loads (g/year) simulated with and without stormwater treatment.

Table 5-1: Comparison of model results with and without treatment. All loads are in g/year.

Model Unit	TSS			Particulate Copper			Dissolved Copper			Particulate Zinc			Dissolved Zinc		
	No treatment	Treated	Reduction (%)	No treatment	Treated	Reduction (%)	No treatment	Treated	Reduction (%)	No treatment	Treated	Reduction (%)	No treatment	Treated	Reduction (%)
1	94052362	94052362	0	651	651	0	54	54	0	3718	3718	0	7534	7534	0
2	13561965	10829269	20	1673	88	95	1172	116	90	9961	1341	87	26844	18277	32
3	41096303	33440353	19	5070	456	91	3551	805	77	30184	5020	83	81344	56385	31
4	8209429	8023523	2	1743	1665	4	1272	1272	0	7784	7551	3	16593	16593	0
5	8469362	3617451	57	8725	455	95	6071	560	91	55956	11742	79	209390	179927	14
6	8789204	6138238	30	7280	4237	42	4988	3741	25	42279	24602	42	113182	90547	20
7	9140861	5889075	36	5694	1446	75	3837	1993	48	31403	8962	71	55666	38933	30
8	11782747	7980569	32	7256	3233	55	4925	1235	75	38096	17820	53	34578	12971	62
9	4617664	2928056	37	980	292	70	716	319	55	4378	1470	66	9333	6602	29
10	10607453	10312984	3	909	853	6	645	629	2	5604	5436	3	19702	19639	0
11	10196173	8959203	12	873	476	46	620	326	47	5386	2614	51	18938	2247	88
12	13940738	8652827	38	8585	1553	82	5827	3824	34	45074	8560	81	40911	24740	40
13	14169204	12204949	14	8726	6786	22	5923	5823	2	45812	35323	23	41582	33465	20
14	14908067	14908067	0	103	103	0	8	8	0	589	589	0	1194	1194	0

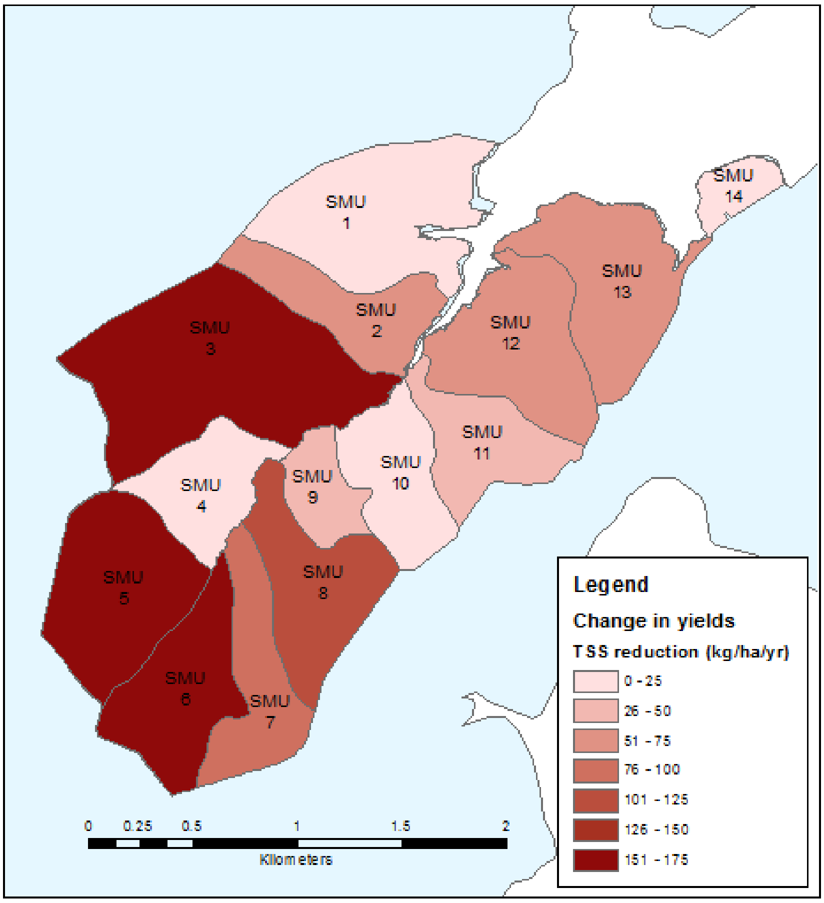


Figure 5-16:Comparison of pre- and post-treatment showing the reduction (%) in simulated TSS yields. The map shows output from ArcMap in layout view with a scale and legend added using standard GIS display tools.

6 Editing

The C-CALM toolbar is provided with tools which can be used to change or delete treatment options or the links between them. These are illustrated in the sections below.

6.1 Editing treatment options

In this example, the set-up for SMU 8 (raingarden, generic treatment and porous paving) from Example 5.1.4 will be changed to demonstrate the editing tools. The design settings for the raingarden will be altered and porous paving will be removed.

6.1.1 Changing treatment set-up

In this example (Figure 6-1), the raingarden treatment set-up for SMU 8 will be adjusted so that raingardens no longer treat runoff from paved surfaces, but receive runoff from 75% of coated galvanised steel roofs. The expected level of removal for dissolved metals will be reduced from high to low. The new treatment configuration is shown below.

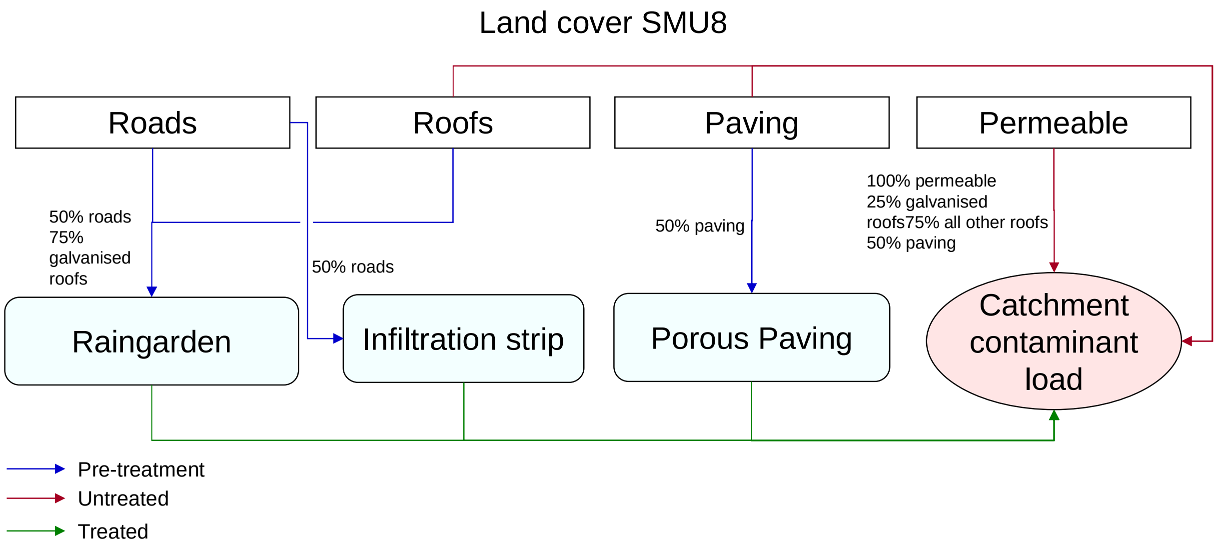
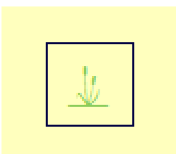
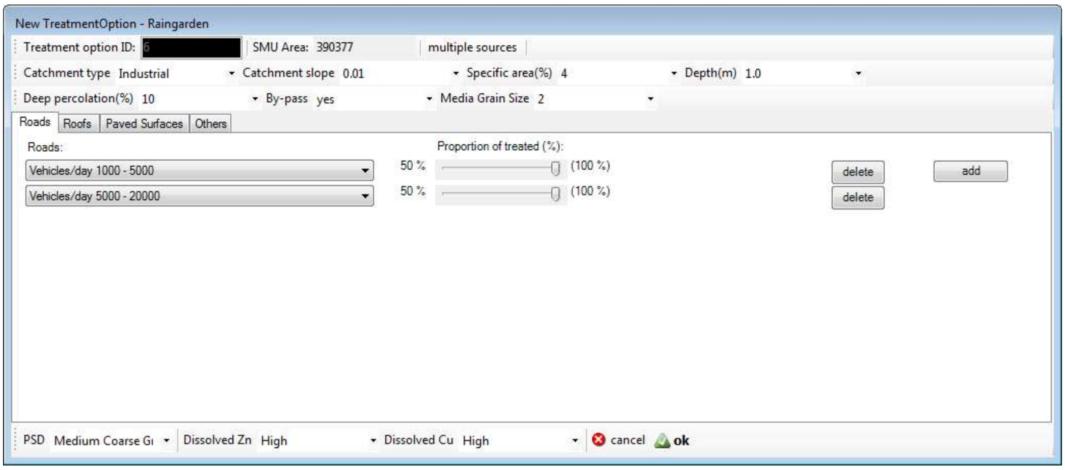


Figure 6-1: Edited stormwater treatment options for SMU 8, a. raingardens with changed set-up options.

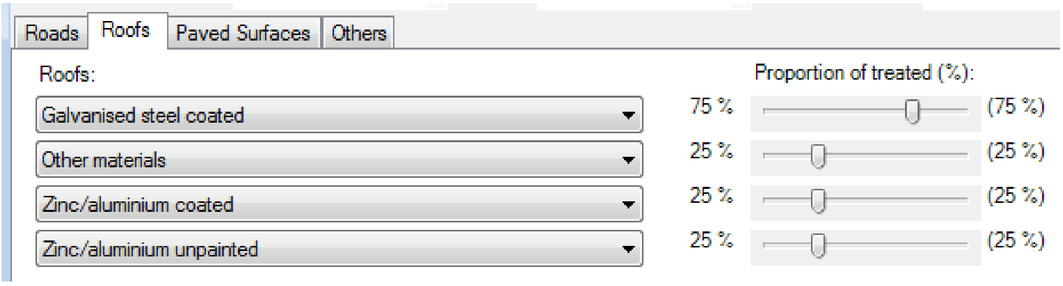
1. Click on the *edit treatment* icon.

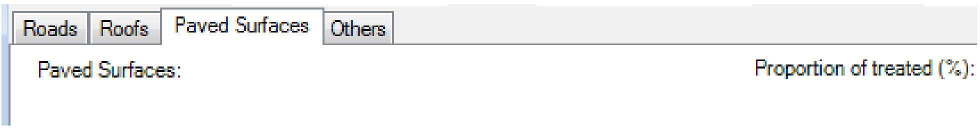
2. Click and drag a box around the treatment option to be edited – this will select the option and open its set-up window.



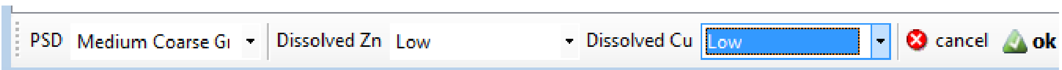


3. Land covers treated can be edited by adjusting the proportion slider or by deleting or adding cover types. In this example, roof runoff treated by raingardens has been increased for coated galvanised steel roofs and runoff from paving removed.



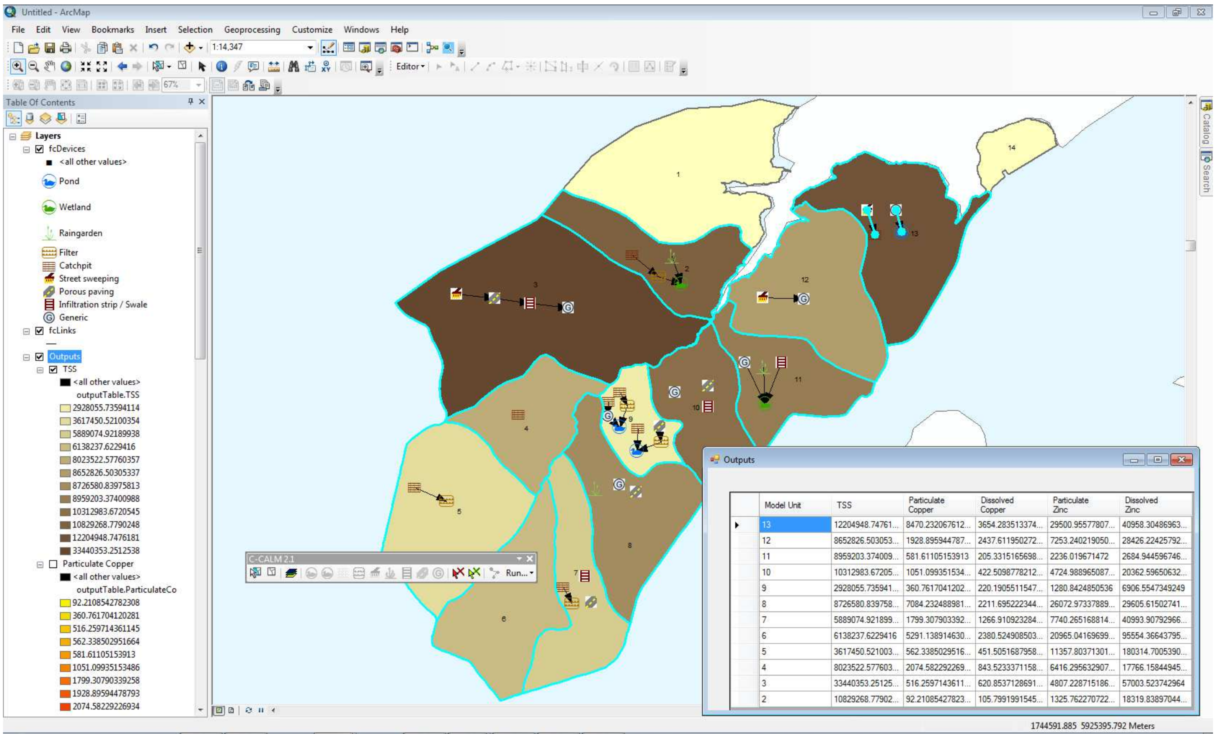


4. Treatment options can be changed by altering the choice in the drop-down menus. Here the treatment level for dissolved metals has been adjusted to low.



5. Clicking Cancel will close the box without saving the changes. Clicking OK will save the changes.

6. Once editing is complete, C-CALM can be re-run as normal.



The impact of the change in the raingarden settings on the total loads simulated for the SMU can be seen in Table 6-1.

Table 6-1: Comparison of contaminant loads simulated for SMU 8 with changed raingarden settings.

Treatment scenario	TSS	Particulate Copper	Dissolved Copper	Particulate Zinc	Dissolved Zinc
Untreated SMU load (kg/year)	11783	7	5	38	35
Original level of treatment (%)	32	55	75	53	62
Edited level of treatment (%)	26	22	29	18	27

6.1.2 Removing a treatment option

In this example (Figure 6-2), in addition to the edits made to the raingarden settings, porous paving has been removed as a treatment option for the SMU.

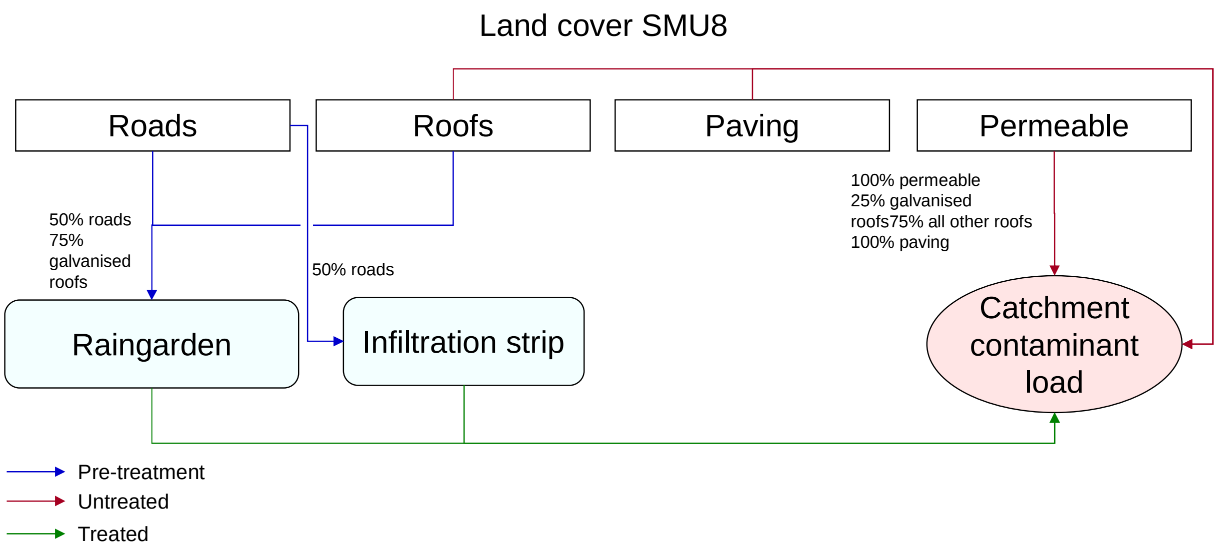
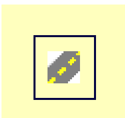


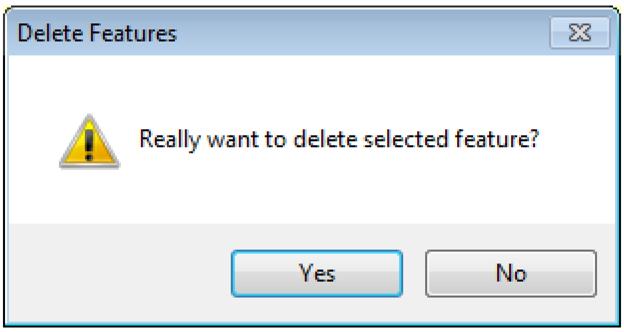
Figure 6-2: Edited stormwater treatment options for SMU 8, b. raingardens with changed set-up options and porous paving removed.

1. Click on the *delete treatment* icon.

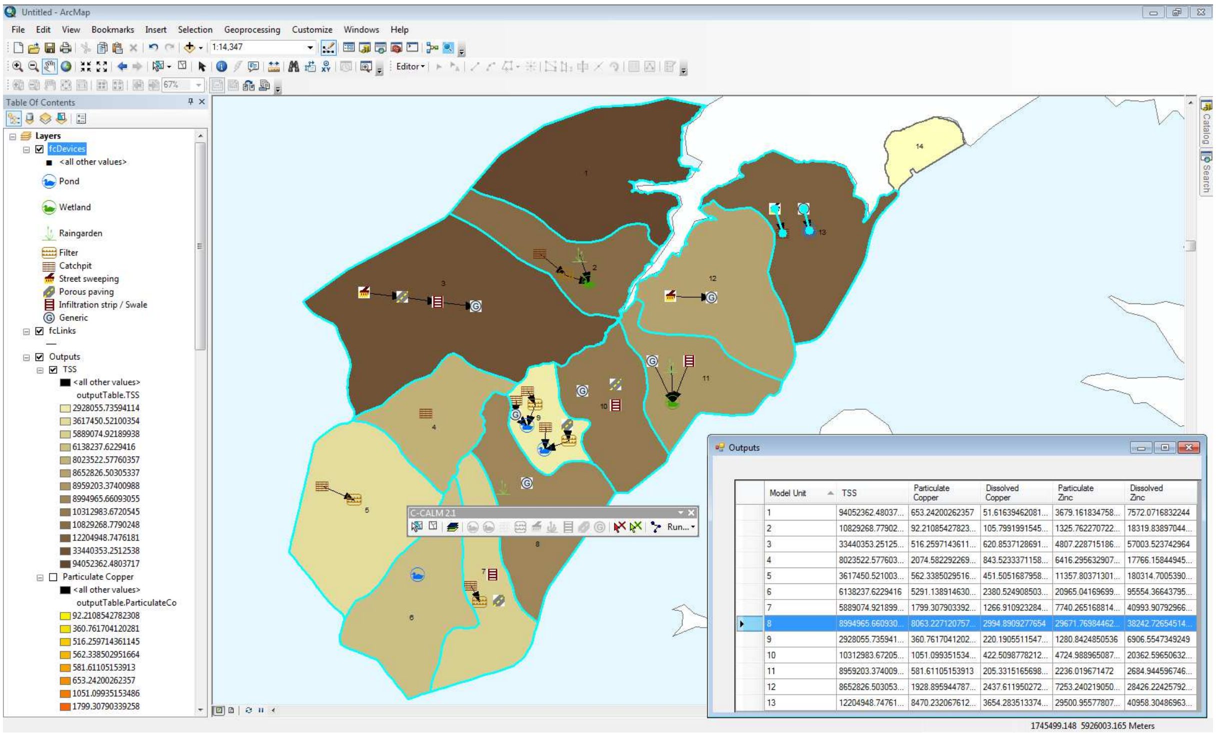
2. Click and drag a box around the treatment option to be removed.



3. C-CALM will request confirmation before deleting the option. Clicking yes will remove the treatment option.



4. C-CALM can be run as normal.



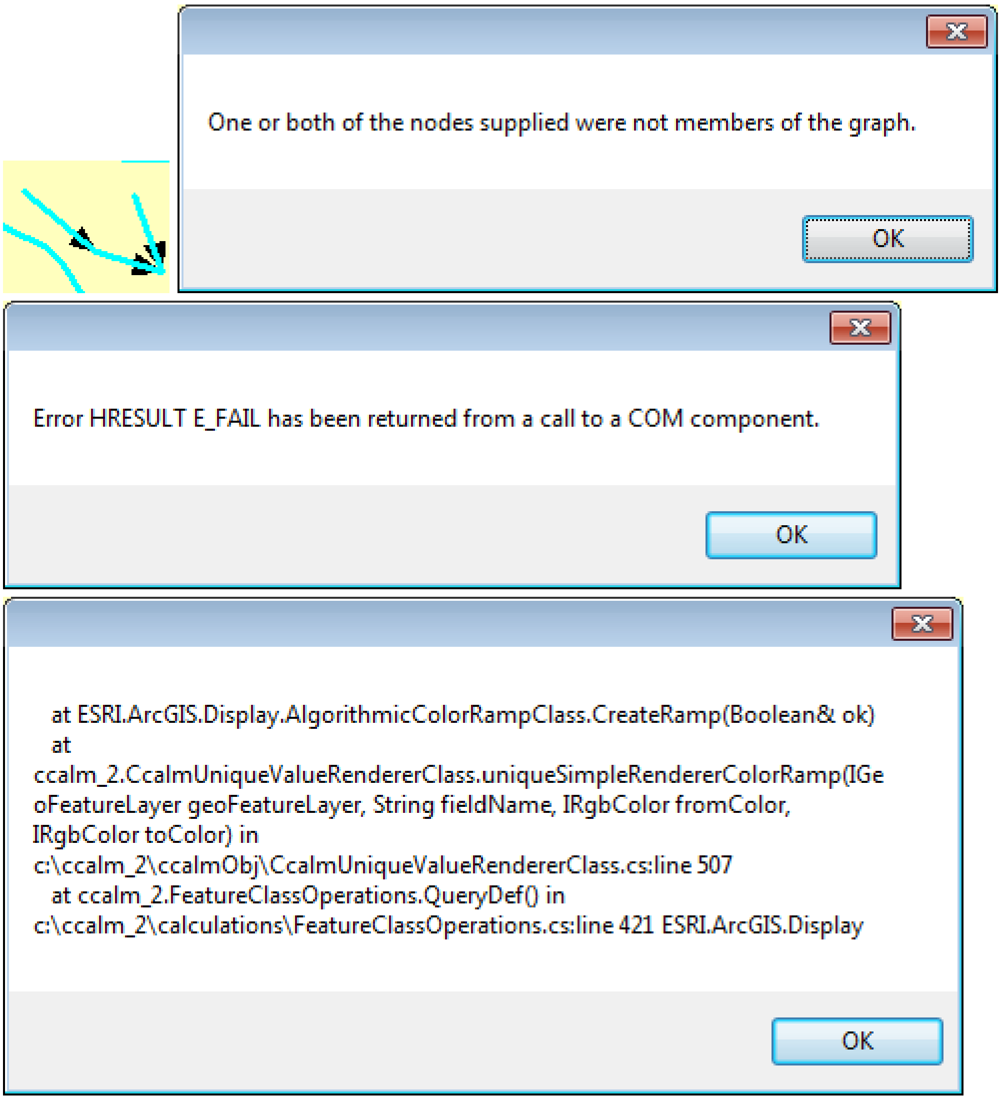
The impact of the change in the raingarden settings and removal of porous paving on the total loads simulated for the SMU can be seen in Table 6-2.

Table 6-2: Comparison of contaminant loads simulated for SMU 8 with changed raingarden settings and removal of porous paving.

Treatment scenario	TSS	Particulate Copper	Dissolved Copper	Particulate Zinc	Dissolved Zinc
Untreated SMU load (kg/year)	11783	7	5	38	35
Original level of treatment (%)	32	55	75	53	62
Edited level of treatment (%)	24	11	4	7	7

5. To remove all treatment options from the geo-database, follow the instruction in Section 4.5.

TROUBLE SHOOTING: What happens if I delete a treatment train and not the links?



These messages occurs if you remove linked treatments, but forget to remove the links, and then try running C-CALM. C-CALM will run but not results will be returned. See Section **Error! Reference source not found.** below.

6.1.3 Adding and removing links

In this example (Figure 6-3), the links between treatment options in the three to one train given in Section 5.2.3 (SMU 11) is adjusted to create a new train. The link between the generic treatment option and the wetland is removed and a new link between Generic treatment and swales created. The new treatment train configuration is as follows:

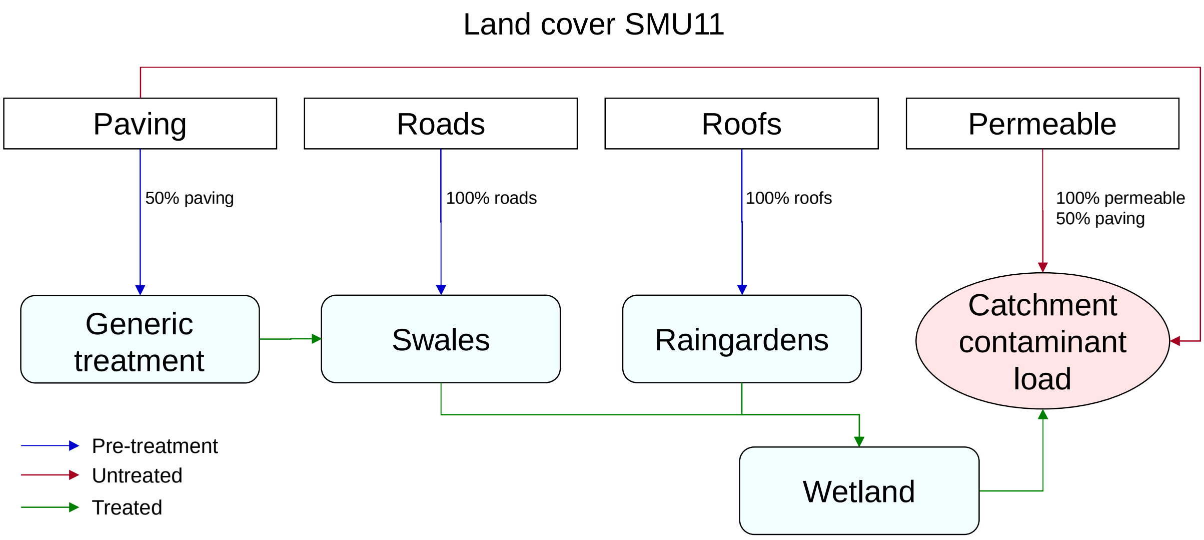
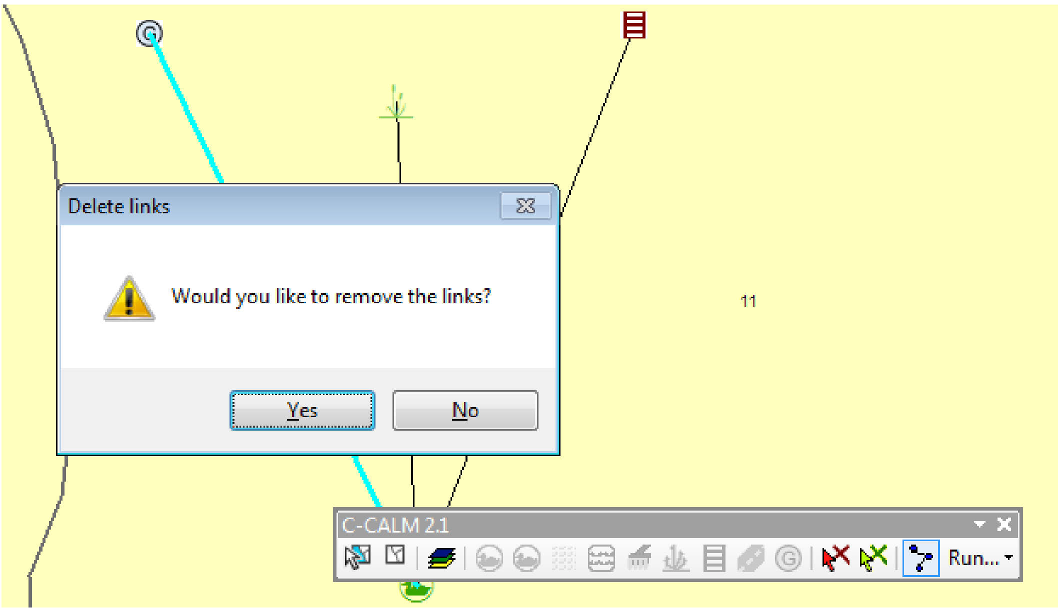


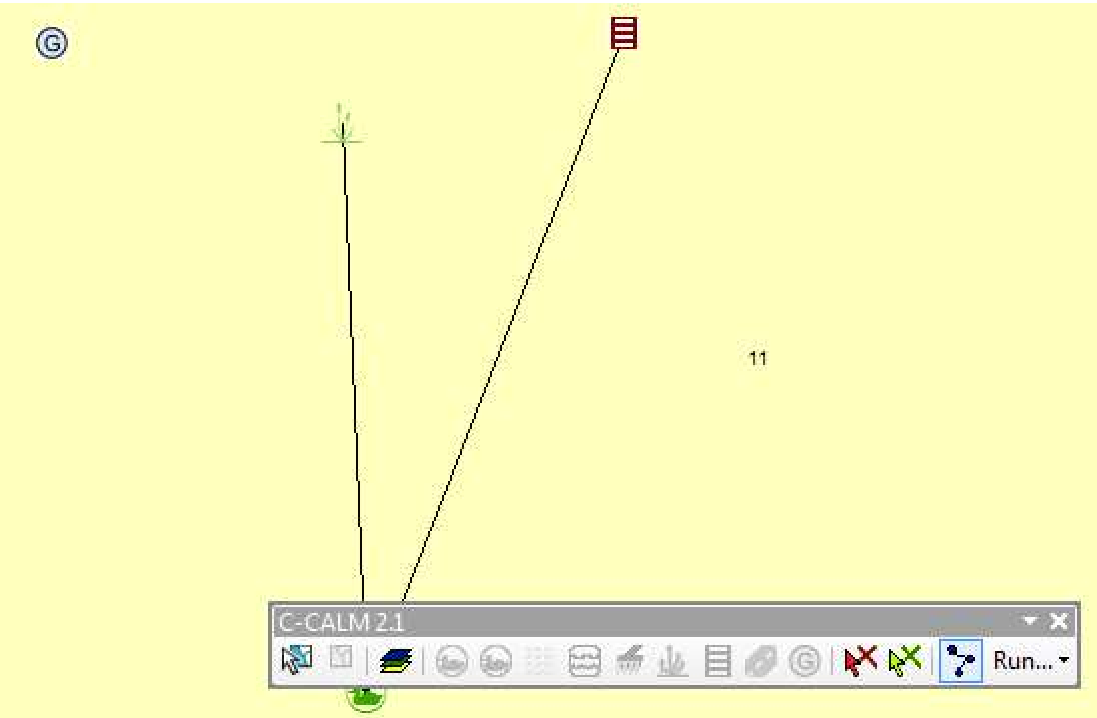
Figure 6-3: Edited stormwater treatment options for SMU 11, link between generic treatment and wetland replaced by a link between generic treatment and swales .

1. Highlight the *fcdevices* shape file in the *TOC* to activate the model tools and click on the *links* icon.

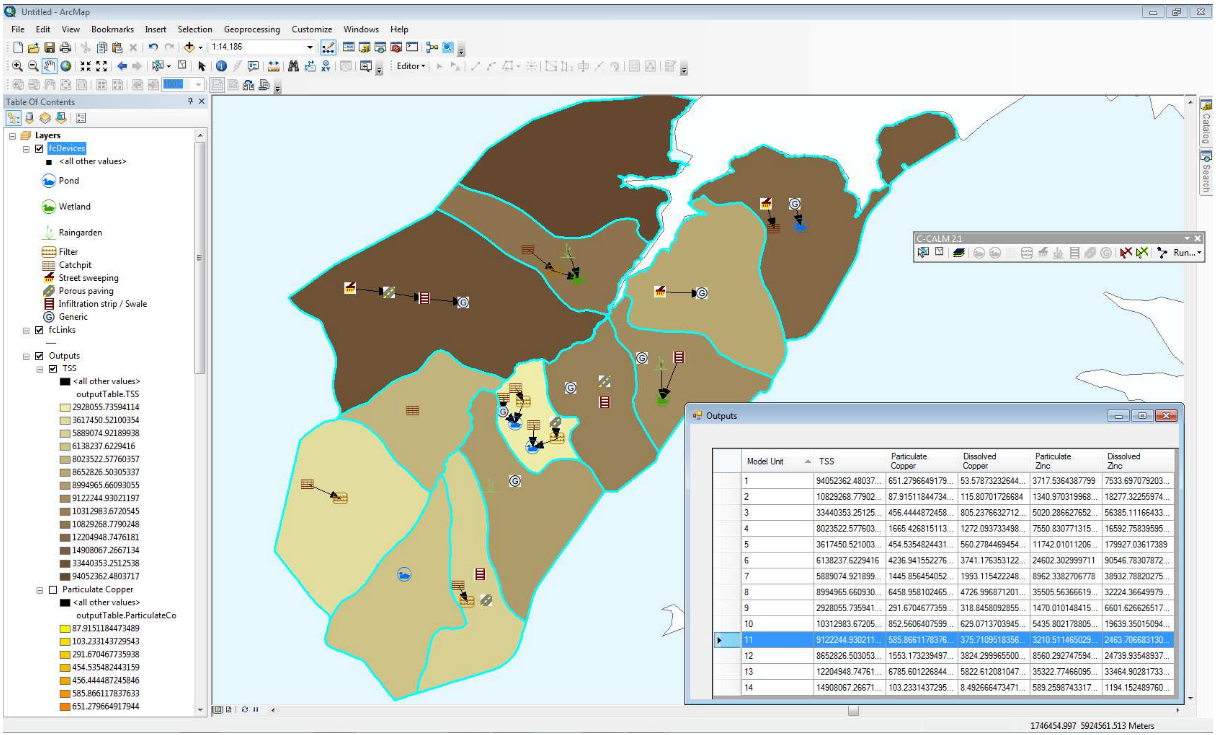
2. Hold down the *Ctrl* key and right click on the link to be removed. This will select the link and bring up a box asking for confirmation that the link should be removed.



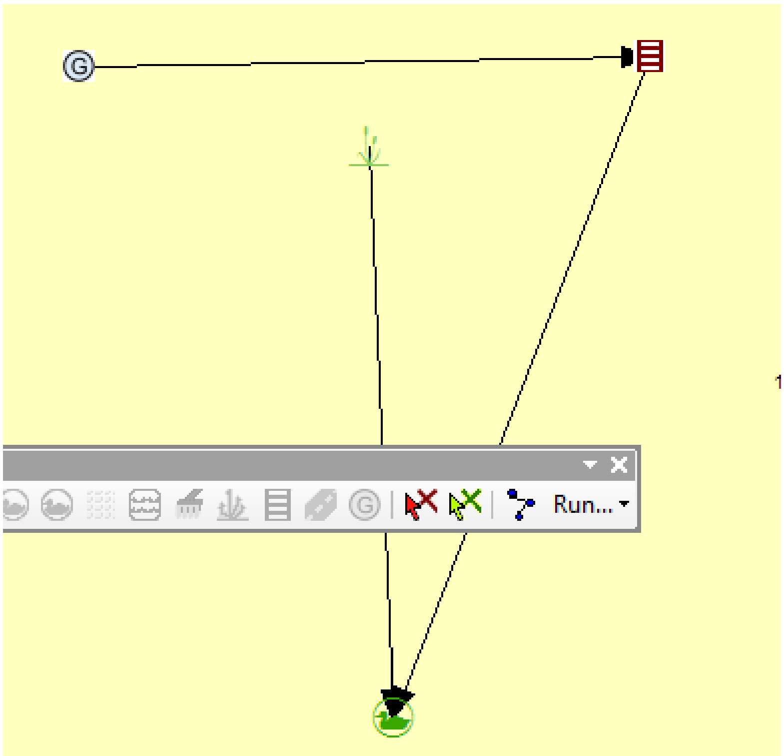
3. Clicking *Yes* will remove the link.



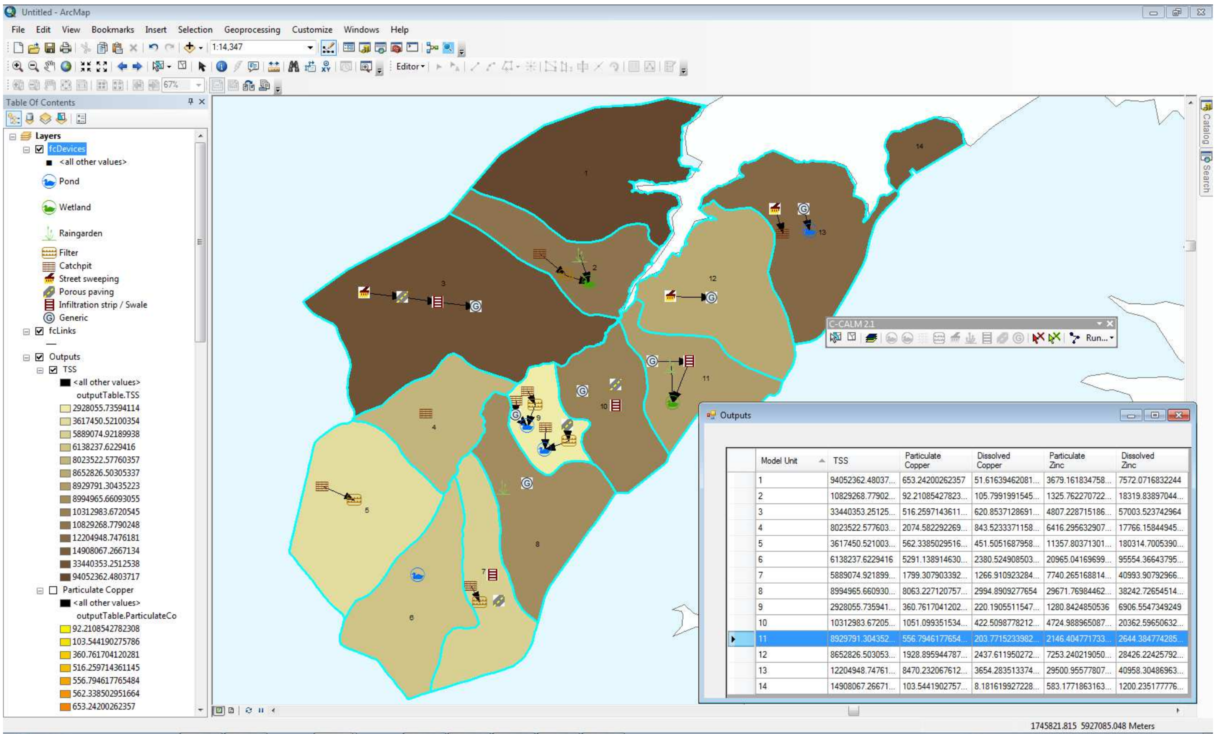
4. Provided that the downstream link was not set to *train only*, C-CALM can be run as normal. If the downstream treatment option is set to *train only* and there are no other input devices, CLUES will return an error message (see Section 5.2.1, trouble shooting).



5. New links can be added by clicking and dragging with the *links* icon activated to draw an arrow between options following the instructions in Section 5.2.1. Here a new link has been added between porous paving and swales.



6. Once the links are correct, C-CALM can be run as normal.



The impact of the linking the generic treatment to the infiltration surface treatment option on the simulated SMU loads are as follows (Table 6-3):

Table 6-3: Comparison of contaminant loads simulated for SMU 11 with the generic treatment option linked to swales.

Treatment scenario	TSS	Particulate Copper	Dissolved Copper	Particulate Zinc	Dissolved Zinc
Untreated SMU load (kg/year)	10196	0.9	0.6	5.4	18.9
Original level treatment (%)	12	46	47	51	88
Edited level of treatment (%)	12	48	48	53	88

In this example the different configuration has a minimal effect on SMU overall treatment levels.

6.2 Editing land use

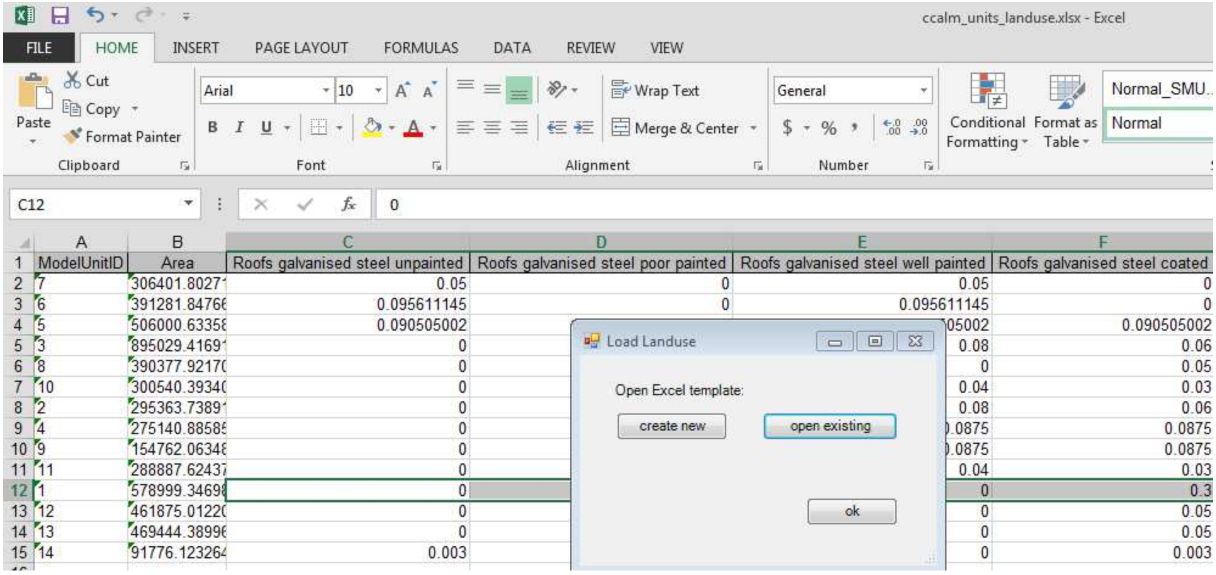
Land use can be changed by inputting new land use data into the model set-up, this requires ArcMap to be closed and reopened. C-CALM will save any treatment options in the geo-database between sessions.

In this example, SMU 1 is developed from rural to high density residential.

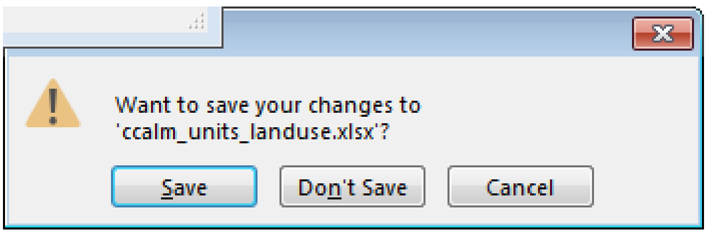
1. Open C-CALM and set up the sub-catchment shape file following the instructions in Section4.2

2. When prompted, open the existing Excel land use template. The spreadsheet can be edited directly and then saved. It is recommended that land use scenarios be saved in a separate master spreadsheet and are copied into *ccalm_units*_landuse.xlsx

   Having a master spreadsheet will allow reference to land use scenarios at a later stage. For instance, the master could hold scenarios for pre-, during and post-development land use.



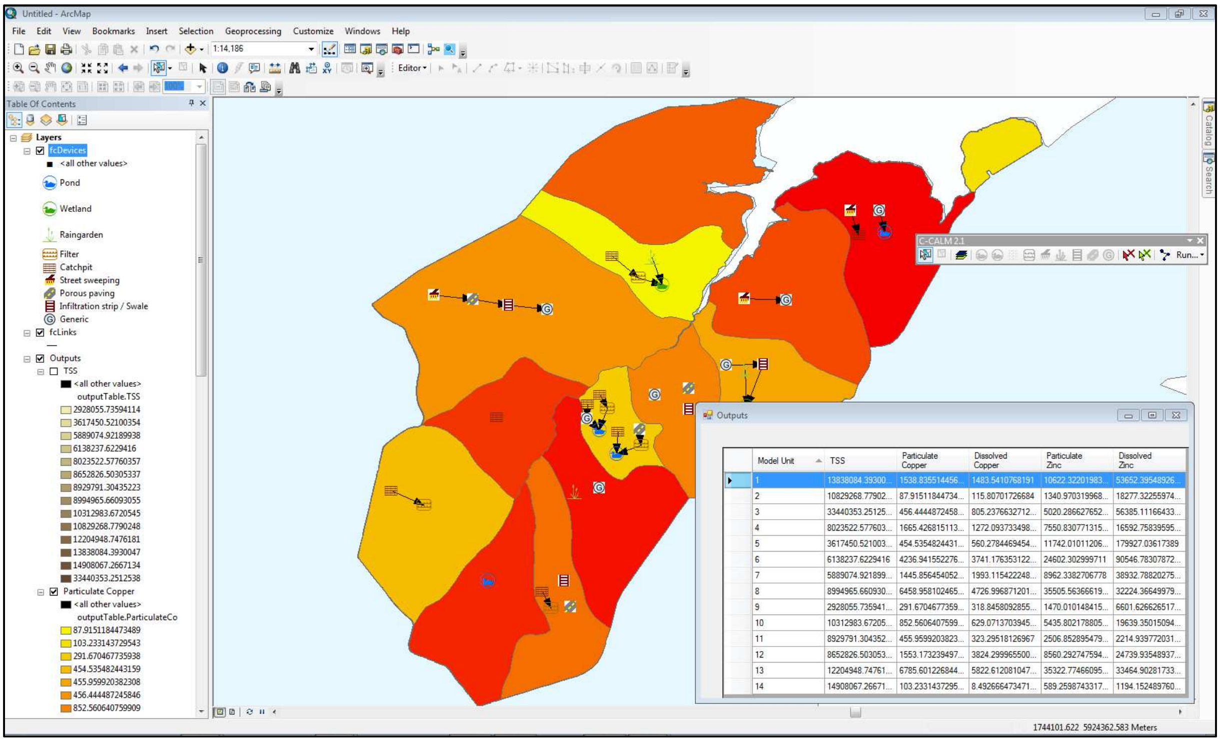
   Click OK and save the spreadsheet in Excel.



3. Alternatively, a new *ccalm_units*_landuse.xlsx spreadsheet can be created with new data copied and pasted in.

4. Selecting the *ccalm_units* shape file in the Table of Contents will open *fcdevices* and display all the treatment options saved in the geodatabase. Selecting *fcdevices* will activate the modelling tools, clicking the *links* icon will display treatment train links.

5. C-CALM can now be run for the new land use.



The effect of changing land use on the simulated loads for SMU 1 are as follows (Table 6-4):

Table 6-4: Comparison of contaminant loads simulated for SMU 1 with rural and high density residential land uses.

Treatment scenario	TSS	Particulate Copper	Dissolved Copper	Particulate Zinc	Dissolved Zinc
Rural land use	94052	0.7	0.1	3.7	7.5
High density residential	13838	1.5	1.5	10.6	53.7
Change in load	-80214	1	1	7	46

There is a large drop in TSS which is due to the higher sediment yields for rural land uses. In contrast, the higher metal yields associated with traffic and impervious urban surfaces leads to a significant increase in metal loads.

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3.4 C-CALM may contain integral third party components. If a third party terminates, or otherwise withdraws or suspends, NIWA's access to any such component, then NIWA may suspend a your access to C-CALM and/or terminate this licence immediately.

3.5 Upon termination or expiration or this licence, you agree to immediately cease use of and delete/destroy C-CALM and any copies thereof (in whatever form). If you are bound by the Public Records Act 2005 to retain a copy of C-CALM, then you may do so, solely for record keeping purposes, but only to the extent necessary for you to meet your obligations under that Act.

4. EXCLUSION OF WARRANTIES

4.1 C-CALM is provided “as is” without warranty of any kind, either express or implied, including, but not limited to, the implied warranties of merchantability and/or fitness for a particular purpose.

4.2 NIWA does not warrant that the functions contained in C-CALM will meet your requirements or that the operation of C-CALM will be uninterrupted or error free, or that C-CALM will not infringe a third party’s intellectual property rights. If you, or a third party through your use of C-CALM, suffered damage, or incurs liability or cost as a result of your use of C-CALM, you (and not NIWA) agree to assume the entire cost of all necessary services, repair or correction.

4.3 You agree that you are using C-CALM for the purpose of a business and therefore any warranties expressed or implied by the Consumer Guarantees Act 1993 shall not apply to this licence or your use of C-CALM.

5. LIMITATION OF LIABILITY / INDEMNITY

5.1 NIWA shall not be liable to you or to any other party for any loss, cost or damage, whatsoever or howsoever caused, arising directly or indirectly in connection with C-CALM or your use thereof.

5.2 Notwithstanding the generality of clause 6.1, NIWA expressly excludes liability for indirect, special, incidental or consequential loss or damage, which may arise in respect of this licence, C-CALM, its use or otherwise, or for loss of profit, business, production, revenue, goodwill or anticipated savings.

5.3 In the event that NIWA incurs any liability whatsoever, such liability will under no circumstances exceed in aggregate, the lesser of the licence fee paid by you for the use of C-CALM or $500.

5.4 You agree to fully indemnify, and keep indemnified, NIWA against any claim, proceeding, loss, cost (including legal costs on a solicitor/own client basis), damage, liability or expense incurred or suffered by it, whether arising in contract, tort (including negligence) or otherwise and arising out of, or in connection with:

i. your use of C-CALM;

ii. use of C-CALM by any third party who has receive CLUE from, or through you; or

iii. a breach of this agreement by you.

6. INTELLECTUAL PROPERTY

6.1 You acknowledge that any and all copyright, trade marks, patents, design registrations, trade-secrets, know-how and other intellectual property, subsisting in or used in connection with, C-CALM (including but not limited to all code, images, photographs, animations, video, audio, music, text, data incorporated in C-CALM) are and remain the sole property of NIWA (or any other third party owner NIWA licences intellectual property from).

6.2 Any modifications or alterations of C-CALM shall remain the property of NIWA in all respects, whether modified or altered by you, NIWA or a third party, and whether or not such modifications or alterations are authorised by NIWA.

7. CONFIDENTIAL INFORMATION

7.1 You agree that all software, information, data, drawing, specifications, documentation, software listings, source or object code, which NIWA may have imparted, or may from time to time impart, to you or you gain access to, relating to C-CALM or associated procedures (the “Confidential Information”), is proprietary and confidential.

7.2 You agree that you shall use the Confidential Information solely in accordance with the provisions of this licence and shall not at any time during the licence or after its termination disclose the Confidential Information, either directly or indirectly, to any third party without NIWA’s prior written consent.

7.3 You may only disclose such Confidential Information to those employees who require the information to use C-CALM. Prior to disclosing such Confidential Information, you will advise those employees of the confidential nature of that information, and ensure they agree to be bound by the obligations under this licence.

7.4 Upon the expiry or termination of this licence you will, if requested, immediately deliver up to NIWA all copies of C-CALM and all associated documentation and all other Confidential Information within your power, possession or control. You may retain one copy, for solely record keeping purposes, if required to do so by the Public Records Act 2005.

8. GENERAL

8.1 You must not assign, licence, transfer or otherwise deal with, either in whole or in part, the benefit or burden of this Agreement without the prior written consent of NIWA, who’s consent may be withheld in its absolute discretion.

8.2 NIWA may from time to time, in its discretion and without notice to you, vary the terms of this licence and your access to C-CALM.

8.3 Failure or delay by NIWA in enforcing any right or provision of this licence is not to be construed or deemed a waiver of such provision or right, and shall not in any way prejudice NIWA’s right to take subsequent action.

8.4 If any provision of this licence is void or unenforceable for any reason that provision shall, to that extent, be severed from the remaining provisions, which will remain in full force and effect.

8.5 This licence will be governed by and construed in all respects in accordance with the laws of New Zealand and you agree to submit to the jurisdiction of the New Zealand Courts.

Appendix B Hypothetical land cover and treatment options

This appendix gives the set-up information used to produce the treatment examples given in this manual. Note that the modelled land use and treatment options for the Waiarohia Catchment DO NOT reflect actual development plans for the catchment. Permission to use the catchment shape files for this manual was granted by the former Waitakere City Council (Chin, 2009).

Table B-1: Modelled treatment options by SMU.

SMU	Land use	Section	PSD	Cover type	Catchpit	Insert	Filter	Porous paving	Rain-garden	Swale / infiltation	Pond	Wet-lands	Generic
1	Rural pasture (edited to Residential high density)	6.2	Medium coarse	Roofs	-	-	-	-	-	-	-	-	-
				Roads	-	-	-	-	-	-	-	-	-
				Paved	-	-	-	-	-	-	-	-	-
2	Residential high density	5.2.7	Mixed	Roofs	-	-	-	-	✓	-	✓	-	-
				Roads	✓	-	✓	-	-	-	✓	-	-
				Paved	✓	-	✓	-	-	-	✓	-	-
3	Residential high density	5.2.6	Coarse	Roofs			-	-		✓-	-	-	✓
				Roads	-	-	-	✓-		✓-	-	-	✓
				Paved	-		-	✓-		✓	-	-	✓
4	Commercial	5.1.1	Coarse	Roofs	-	-	-	-	-	-	-	-	-
				Roads	✓	-	-	-	-	-	-	-	-
				Paved	-	-	-	-	-	-	-	-	-
5	Old Industrial	5.2.1	Medium	Roofs	-		-	-	-	-	-	-	-
				Roads	✓	-	✓	-	-	-	-	-	-
				Paved	✓		✓	-	-	-	-	-	-
6	Old Industrial	5.1.2	Medium Coarse	Roofs	-	-	-	-	-	-	✓	-	-
				Roads	-	-	-	-	-	-	✓	-	-
				Paved	-	-	-	-	-	-	✓	-	-
7	Old Industrial	5.2.4	Medium Coarse	Roofs	-	-	-	-	-	✓-	-	-	-
				Roads	✓	-	✓	-	-	-	-	-	-
				Paved	-	-	-	✓	-	✓	-	-	-
8 original	New Industrial	5.1.4	Medium	Roofs	-	-	-	-	✓	-	-	-	-
				Roads	-	-	-	-	✓	-	-	-	✓
				Paved	-	-	-	✓	✓	-	-	-	-

SMU	Land use	Section	PSD	Cover type	Catchpit	Insert	Filter	Porous paving	Rain-garden	Swale / infiltation	Pond	Wet-lands	Generic
8 edit 1	New Industrial	6.1.1	Medium	Roofs	-	-	-	-	✓	-	-	-	-
				Roads	-	-	-	-	✓	-	-	-	✓
				Paved	-	-	-	✓	-	-	-	-	-
8 edit 2	New Industrial	6.1.2	Medium	Roofs	-	-	-	-	✓	-	-	-	-
				Roads	-	-	-	-	✓	-	-	-	✓
				Paved	-	-	-	✓	-	-	-	-	-
9	Commercial	0	Medium coarse	Roofs	-	-	✓	-	-	✓	✓	-	-
				Roads	✓	✓	✓	✓	✓	✓	✓-	-	✓
				Paved	✓	✓	✓	✓	✓	✓	✓	-	✓
10	Residential low density	5.1.3	Medium Coarse	Roofs			-	-	-	-	-	-	
				Roads	-	✓	-	✓	-	✓	-	-	
				Paved			-	-	-	-	-	-	
				Perm.			-	-	-	-	-	-	
11 original	Residential low density	5.2.3	Medium	Roofs			-	-	✓	-	-	✓	
				Roads			-	-	-	✓	-	✓	
				Paved			-	-	✓	-	-	✓	✓
11 edit	Residential low density	**Error! Reference source not found.**	Medium	Roofs			-	-	✓	-	-	✓	-
				Roads			-	-	-	✓	-	✓	-
				Paved			-	-	✓	-	-	✓	✓
				Perm.			-	-	-	-	-	-	
12	New Industrial	0	Medium coarse	Roofs	-	-	-	-	-	-	-	-	✓
				Roads	-	-	-	-	-	-	-	-	✓
				Paved	-	-	-	-	-	-	-	-	✓
13	New Industrial	5.2.6	Mixed	Roofs	-	-		-	-	-	-	✓	✓
				Roads	✓		-	-	-	-	-	-	
				Paved	✓		-	-	-	-	-	-	

SMU	Land use	Section	PSD	Cover type	Catchpit	Insert	Filter	Porous paving	Rain-garden	Swale / infiltration	Pond	Wet-lands	Generic
14	Rural pasture	None	Medium Coarse	Roofs			-	-	-	-	-	-	
				Roads			-	-	-	-	-	-	
				Paved			-	-	-	-	-	-	

Table B-2: Land cover fractions used in the example given in this manual. Impervious surfaces.

Land Cover		SMU ID														
		1 rural	1 urban	2	3	4	5	6	7	8	9	10	11	12	13	14
Roof	Galvanised steel unpainted	0.0030	0	-	-	-	0.0905	0.0956	0.0500	-	-	-	-	-	-	0.0030
	Galvanised steel poor painted	0.0040	0	0.0300	0.0300	-	0.0905	-	-	-	-	0.0300	0.0300	-	-	0.0040
	Galvanised steel well painted	-	0	0.0800	0.0800	0.0875	0.0905	0.0956	0.0500	-	0.0875	0.0400	0.0400	-	-	-
	Galvanised steel coated	0.0030	0.3	0.0600	0.0600	0.0875	0.0905	-	-	0.0500	0.0875	0.0300	0.0300	0.0500	0.0500	0.0030
	Zinc/aluminium unpainted	-	0	-	-	-	-	-	-	0.0500	-	-	-	0.0500	0.0500	-
	Zinc/aluminium coated	0.0020	0	0.0400	0.0400	0.0875	0.0905	0.0956	0.0500	0.0500	0.0875	0.0200	0.0200	0.0500	0.0500	0.0020
	Concrete	-	0	-	-	-	-	-	-	-	-	-	-	-	-	-
	Copper	-	0	-	-	-	-	-	-	-	-	-	-	-	-	-
	Other materials	0.0080	0.2	0.0800	0.0800	0.0875	0.0905	0.0956	0.0500	0.0500	0.0875	0.0800	0.0800	0.0500	0.0500	0.0080
Roads	<1k vpd	0.0151	0.05	-	-	-	-	-	-	-	-	-	-	-	-	0.0151
	1k-5k vpd	-	0.1	0.0444	0.0444	0.0721	0.1211	0.1516	0.1344	0.1344	0.0721	0.0444	0.0444	0.1344	0.1344	-
	5k-20k vpd	-	0	-	-	0.1366	0.0226	0.0762	0.0772	0.0772	0.1366	-	-	0.0772	0.0772	-
	20k-50k vpd	-	0	-	-	-	-	-	-	-	-	-	-	-	-	-
	50k-100k vpd	-	0	-	-	-	-	-	-	-	-	-	-	-	-	-
	>100k vpd	-	0	-	-	-	-	-	-	-	-	-	-	-	-	-
Paving	Commercial	-	0.05	-	-	0.1600	-	-	-	-	0.1600	-	-	-	-	-
	Residential	-	0.05	0.2400	0.2400	-	-	-	-	-	-	0.1200	0.1200	-	-	-
	Industrial	-	0	-	-	-	0.2500	0.2500	0.2500	0.2500	-	-	-	0.2500	0.2500	-
Imperviousness (%)		3.5	75.0	57.4	57.4	71.9	93.7	86.0	66.2	66.2	71.9	36.4	36.4	66.2	66.2	3.5

Table B-3: Land cover fractions used in the example given in this manual. Permeable surfaces.

Land Cover		SMU ID														
		1 rural	1 urban	2	3	4	5	6	7	8	9	10	11	12	13	14
Stream Channels		0.0026	0	0.0026	0.0026	-	-	-	-	-	-	-	-	-	0.0026	0.0026
Urban grasslands and trees	Slope <5°	-	0.25	0.4229	0.4229	0.2814	0.0633	0.1398	0.3385	0.3385	0.2814	0.6356	0.6356	0.3385	-	-
	Slope 5-10°	-		-	-	-	-	-	-	-	-	-	-	-	-	-
	Slope >10°	-		-	-	-	-	-	-	-	-	-	-	-	-	-
Construction sites	Slope <5°	-		-	-	-	-	-	-	-	-	-	-	-	-	-
	Slope 5-10°	-		-	-	-	-	-	-	-	-	-	-	-	-	-
	Slope >10°	-		-	-	-	-	-	-	-	-	-	-	-	-	-
Stable forest	Slope <10°	-		-	-	-	-	-	-	-	-	-	-	-	-	-
	Slope 10-20°	-		-	-	-	-	-	-	-	-	-	-	-	-	-
	Slope >20°	-		-	-	-	-	-	-	-	-	-	-	-	-	-
Exotic production forest	Slope <10°	-		-	-	-	-	-	-	-	-	-	-	-	-	-
	Slope 10-20°	-		-	-	-	-	-	-	-	-	-	-	-	-	-
	Slope >20°	-		-	-	-	-	-	-	-	-	-	-	-	-	-
Farmed pasture	Slope <10°	0.9623		-	-	-	-	-	-	-	-	-	-	-	0.9623	-
	Slope 10-20°	-		-	-	-	-	-	-	-	-	-	-	-	-	-
	Slope >20°	-		-	-	-	-	-	-	-	-	-	-	-	-	-
Retired pasture	Slope <10°	-		-	-	-	-	-	-	-	-	-	-	-	-	-
	Slope 10-20°	-		-	-	-	-	-	-	-	-	-	-	-	-	-
	Slope >20°	-		-	-	-	-	-	-	-	-	-	-	-	-	-
Horticulture	Unknown soil	-		-	-	-	-	-	-	-	-	-	-	-	-	0.9623
	Sedimentary soil	-		-	-	-	-	-	-	-	-	-	-	-	-	-
	Volcanic soil	-		-	-	-	-	-	-	-	-	-	-	-	-	-

Appendix C Performance rules and treatment boxes for C-CALM treatment options

This appendix shows the literature derived performance rules for each of the C-CALM treatment options.

Media Filters

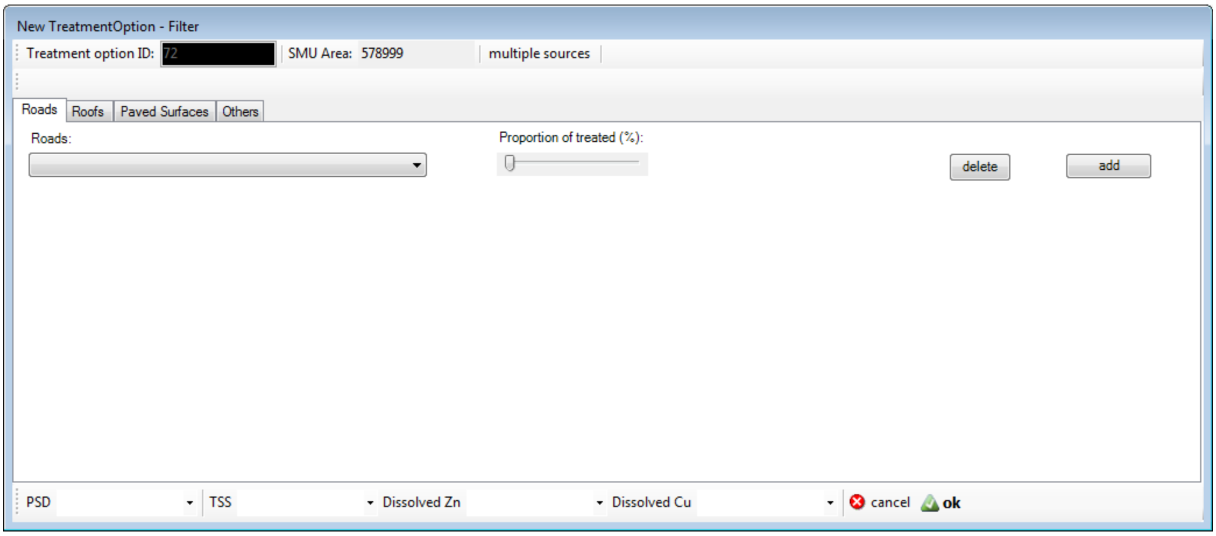
Removal of TSS and metals are user defined:

TSS and particulate metals

Band	Velocity (m/h)	Grain size (µm)	Removal Efficiency (%)		
			Low	Medium	High
1	0.00133	1.5	60	75	95
2	0.00531	3	60	75	95
3	0.0424	6	60	75	95
4	0.254	12	60	75	95
5	1.47	24	60	75	95
6	6.77	48	60	75	95
7	29.78	96	60	75	95
8	89.80	192	60	75	95
9	198.23	384	60	75	95

Dissolved metals

Removal Efficiency	Dissolved Cu	Dissolved Zn
Low	40	20
Medium	70	60
High	95	95



Swales and infiltration strips (vegetated bio-filters)

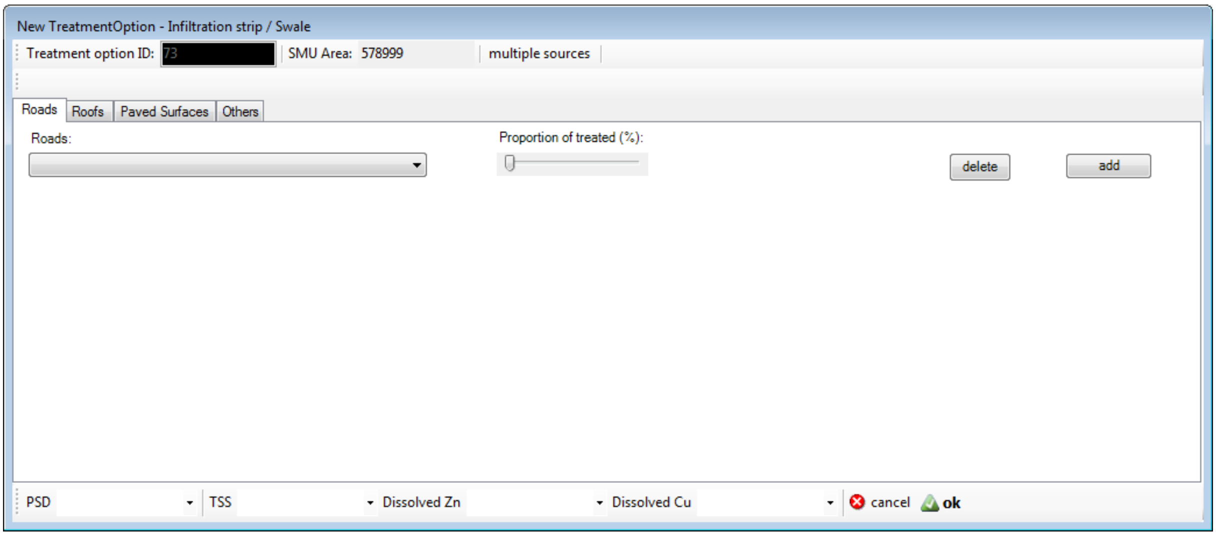
Removal of TSS and metals are user defined:

TSS and particulate metals

Band	Velocity (m/h)	Grain size (µm)	Removal Efficiency (%)		
			Low	Medium	High
1	0.00133	1.5	50	60	90
2	0.00531	3	50	60	90
3	0.0424	6	50	60	90
4	0.254	12	50	60	90
5	1.47	24	50	60	90
6	6.77	48	50	60	90
7	29.78	96	50	60	90
8	89.80	192	50	60	90
9	198.23	384	50	60	90

Dissolved metals

Removal Efficiency	Dissolved Cu	Dissolved Zn
Low	5	10
Medium	40	60
High	90	90

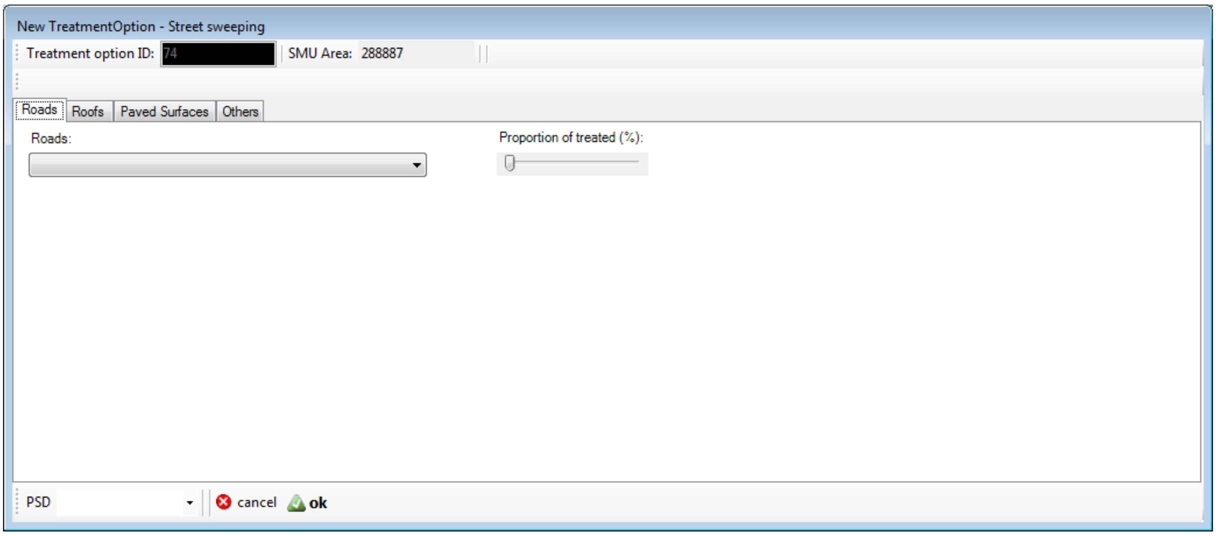


Street sweeping

Removal of TSS and particulate metals is determined by grain size. Dissolved metals are not treated.

TSS and particulate metals

Band	Velocity (m/h)	Grain size (µm)	Removal (%)
1	0.00133	1.5	0
2	0.00531	3	0
3	0.0424	6	0
4	0.254	12	5
5	1.47	24	15
6	6.77	48	30
7	29.78	96	40
8	89.80	192	50
9	198.23	384	60



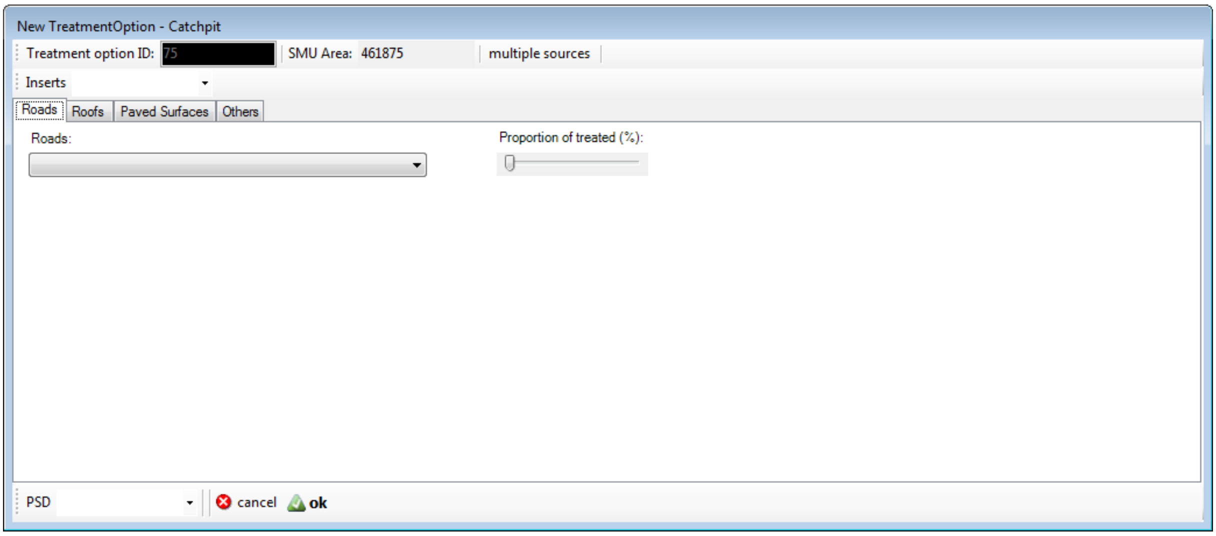
Catchpits

Removal of TSS and particulate metals is determined by grain size. Dissolved metals are not treated.

Catchpits are only available for roads and paved surfaces.

TSS and particulate metals

Band	Velocity (m/h)	Grain size (µm)	Removal Efficiency (%)	
			No Insert	Insert
1	0.00133	1.5	0	0
2	0.00531	3	0	0
3	0.0424	6	0	0
4	0.254	12	0	0
5	1.47	24	0	0
6	6.77	48	0	20
7	29.78	96	0	60
8	89.80	192	20	80
9	198.23	384	40	90



Porous paving

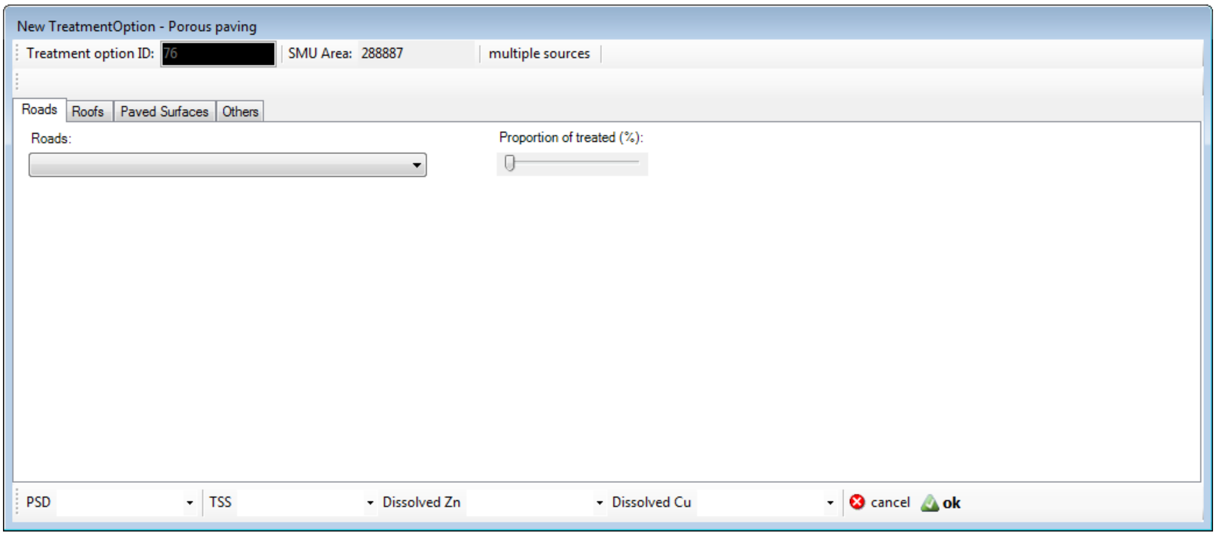
Porous paving is only available for runoff from roads and paved surfaces. Removal of TSS and metals are user defined:

TSS and particulate metals

Band	Velocity (m/h)	Grain size (µm)	Removal Efficiency (%)		
			Low	Medium	High
1	0.00133	1.5	25	60	95
2	0.00531	3	25	60	95
3	0.0424	6	25	60	95
4	0.254	12	25	60	95
5	1.47	24	25	60	95
6	6.77	48	25	60	95
7	29.78	96	25	60	95
8	89.80	192	25	60	95
9	198.23	384	25	60	95

Dissolved metals

Removal Efficiency	Dissolved Cu	Dissolved Zn
Low	25	25
Medium	60	60
High	95	95



Raingardens / Bio-retention

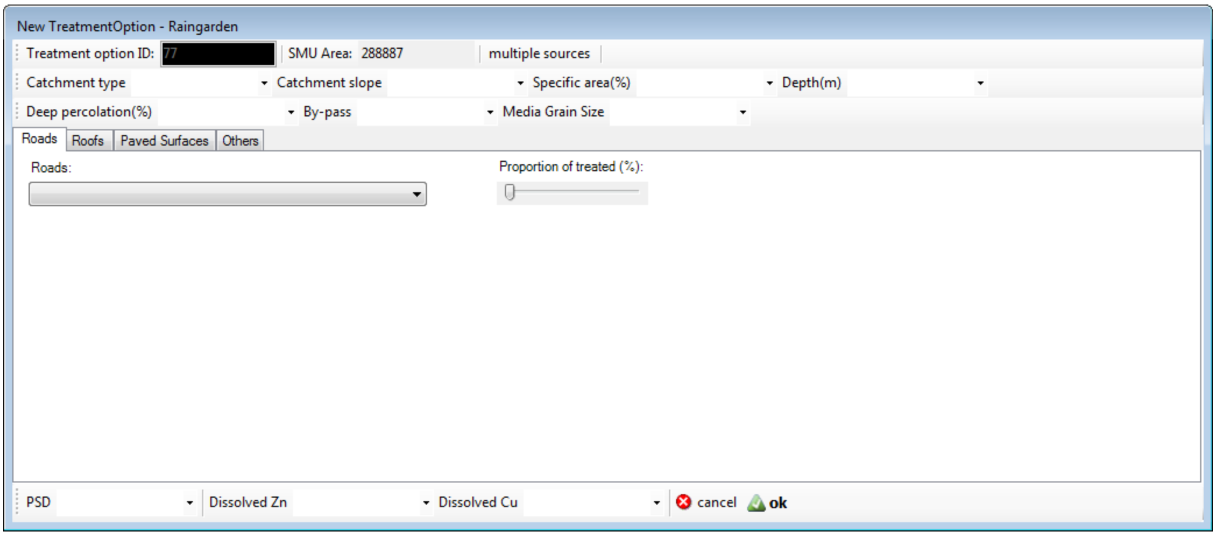
TSS and particulate metal removal are simulated. Users are required to enter the following parameters for the performance rule query library:

Catchment Parameters:	
Predominant land use and impervious percentage of surface area:	Residential – 100% Commercial – 100% Industrial – 100%
Average catchment slope:	0.005, 0.01, 0.03 and 0.05
Raingarden (bio-retention) Parameters:	
Specific area: (ratio of raingarden surface area relative to the contributing area)	100, 200, 400 and 600 m^2 /ha1 expressed as fractions: 1, 2, 4 and 6
Depth:	0.5, 1.0 and 1.5 m
Bypass:	Yes, or no (if yes, generic parameters for the bypass outflow weir)
Deep percolation to groundwater:	0% (isolated from groundwater), 10%, 20%, 40% and 50%
Media median grain size (diameter)*	0.5 mm (medium sand), 1 mm (coarse sand), 2 mm (very coarse sand), 3 mm (gravel - e.g. pumice soils)

Dissolved metal removal is user defined:

Dissolved Metal

Removal Efficiency	Dissolved Cu	Dissolved Zn
Low	20	30
Medium	50	60
High	95	95



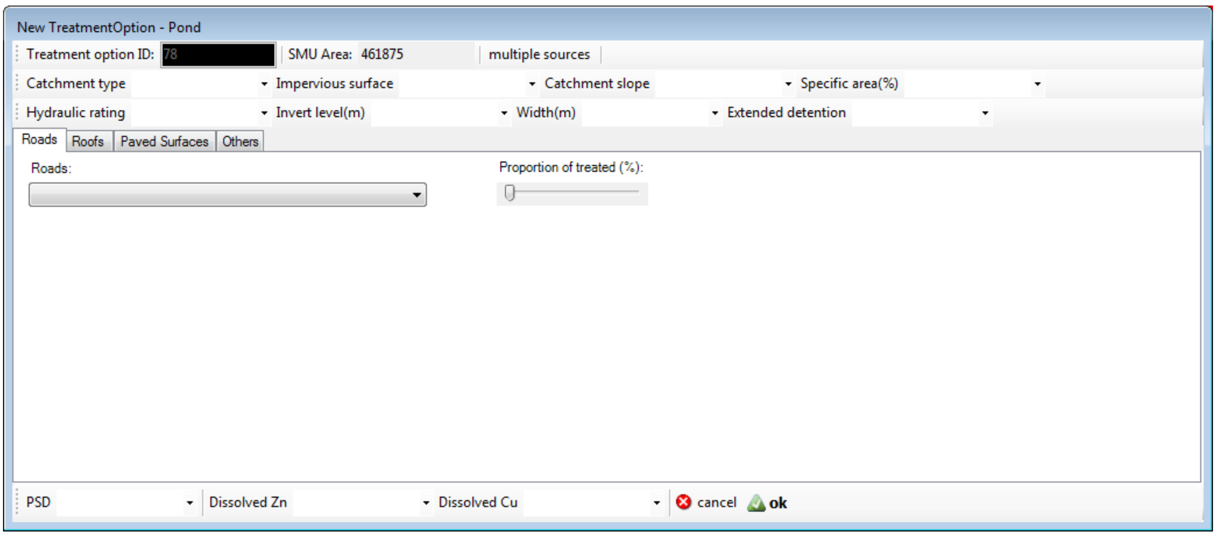
Ponds

TSS and particulate metal removal are simulated. Users are required to enter the following parameters for the performance rule query library:

Catchment Parameters:	
Predominant land use and impervious percentage of surface area:	Residential – 20%, 40% and 60% Commercial – 60%, 75% and 90% Industrial – 60%, 75% and 90%
Average gutter slope:	0.005, 0.01, 0.03 and 0.05
Pond Parameters:	
Specific area: (ratio of wet surface area relative to the area contributing impervious surfaces))	50, 100, 150, 200 and >250 m^2/ha expressed as fractions: 0.5, 1, 1.5, 2 and 2.5
Invert level:	0.5, 1.0 and >1.5 m
Width (or width equivalent) of outlet weir:	1, 2 and 3 m
Extended detention:	Yes, or no (if yes, slot weir width is set to 10% of the outlet weir width, depth = 30cm)
Hydraulic rating: (see Appendix Two for guide)	1 (poor), 3.5 (good) and 8 (excellent)
Particle size distribution:	Fine, medium fine, medium (NURP), medium coarse, and coarse

Dissolved metal removal is user defined:

Removal Efficiency	Dissolved Cu	Dissolved Zn
Low	40	20
Medium	50	40
High	60	80



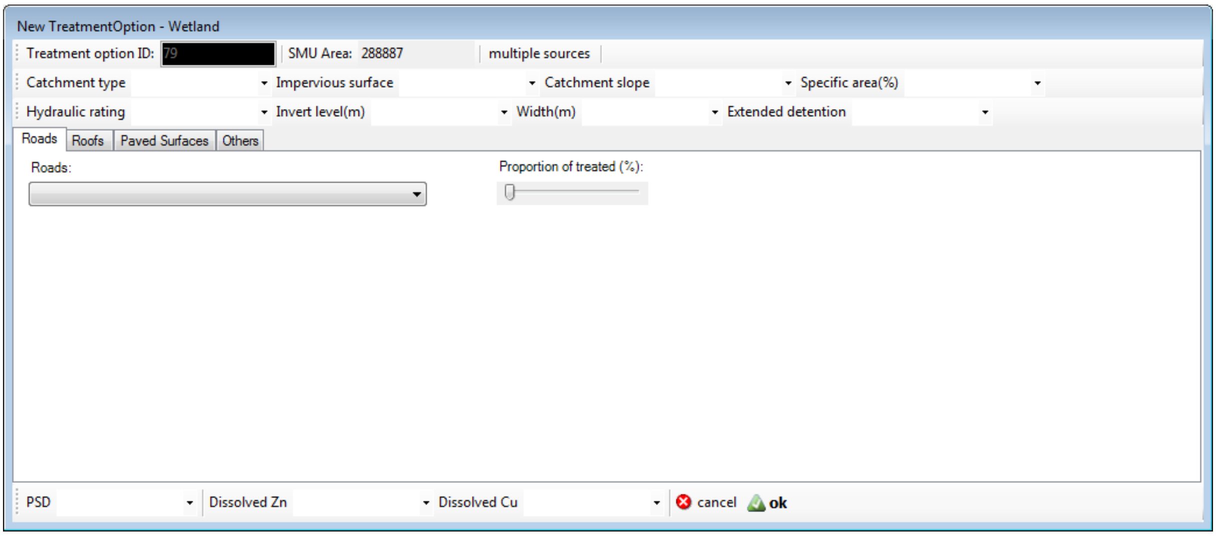
Wetlands

TSS and particulate metal removal are simulated. Users are required to enter the following parameters for the performance rule query library:

Catchment Parameters:	
Predominant land use and impervious percentage of surface area:	Residential – 20%, 40% and 60% Commercial – 60%, 75% and 90% Industrial – 60%, 75% and 90%
Average gutter slope:	0.005, 0.01, 0.03 and 0.05
Pond (and Wetland) Parameters:	
Specific area: (ratio of wet surface area relative to the area contributing impervious surfaces))	50, 100, 150, 200 and >250 m^2/ha expressed as fractions: 0.5, 1, 1.5, 2 and 2.5
Invert level:	0.5, 1.0 and >1.5 m
Width (or width equivalent) of outlet weir:	1, 2 and 3 m
Extended detention:	Yes, or no (if yes, slot weir width is set to 10% of the outlet weir width, depth = 30cm)
Hydraulic rating: (see Appendix Two for guide)	Assumed to be 8 (excellent)
Particle size distribution:	Fine, medium fine, medium (NURP), medium coarse, and coarse

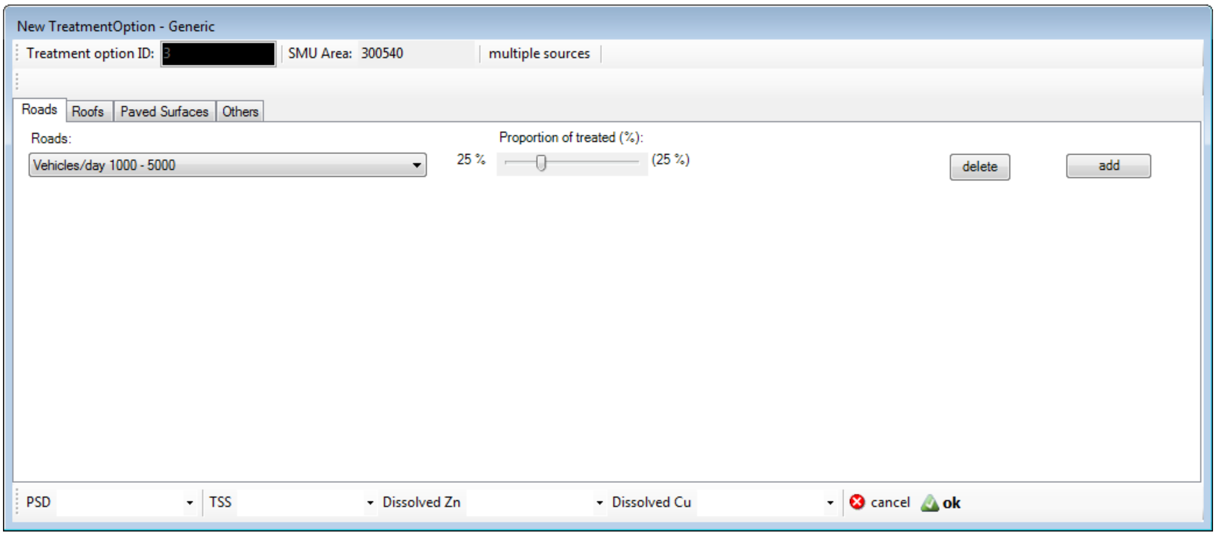
Dissolved metal removal is user defined:

Removal Efficiency	Dissolved Cu	Dissolved Zn
Low	40	20
Medium	50	40
High	60	80



Generic Treatment Option

G All treatment removal efficiencies are set by the user. The option has removal percentages in increments of 5% from 0 to 100% for each contaminant.

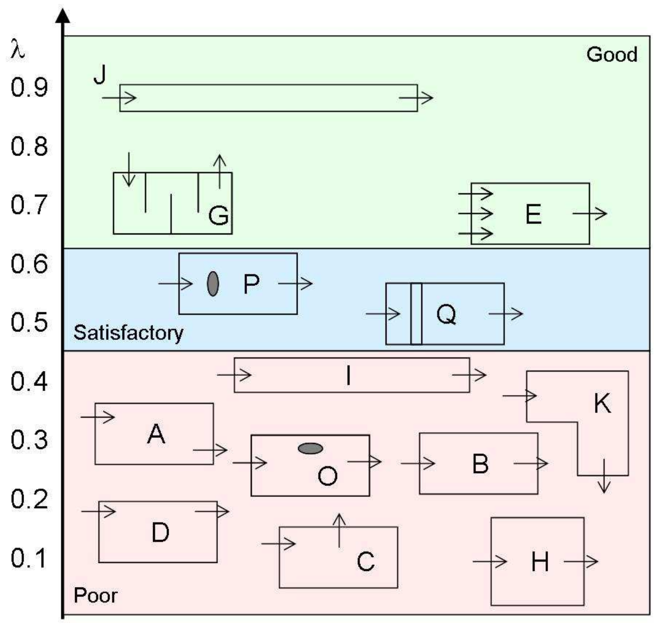


Appendix D Hydraulic Rating Guide

The hydraulic rating is a parameter used in continuously stirred tank reactor models (CSTR) of ideal settling. CSTR modelling is widely-used for simulating settling in detention basins and was used to derive the C-CALM performance rules for ponds and wetlands. The method assumes that there are two types of settling, quiescent and dynamic. A detention basin operates under dynamic conditions during a flow event with water either entering or exiting the basin (i.e, there is a change in the basin volume and stage level). Quiescent settling occurs during the dry period between storms. The relative importance of the two settling periods depends on the size of the pond, the volume of each runoff event, and the length of time between events.

The hydraulic rating is used in the calculation of settling during dynamic conditions. This calculation is based on Hazen theory (Fair and Geyer, 1954) where the basin is approximated as a series of successive tanks with flow from one tank to the next. The hydraulic rating is the conceptual number of tanks in the basin, n; the more tanks there are, the less mixing and short circuiting occurs between sections of the basin. In an exceptional pond the number of tanks n tends to infinity. In a poorly designed pond (n = 1), there is only one tank with continuous mixing horizontally and vertically, turbulence and short circuiting. Generally, n ranges from 1 to 8 in CSTR models of stormwater ponds. The values of n provided for C-CALM are: 1 (poor), 3.5 (good) and 8 (excellent).

Persson et al. (1999), Persson (2000) and Persson and Wittgren (2003) investigated the hydraulic behaviour of a range of pond layouts to guide the choice of a value for n. Hypothetical pond configurations were modelled (2-D MIKE 21) to find an approximate relationship between n and hydraulic efficiency (λ, the ratio of the time to peak concentration at the outlet against the nominal flow detention time). The simulated values for λ and n are given in below and show how the relative locations of the inlet and outlet, the width to length ratio, and the presence of berms, baffles and islands can change hydraulic efficiency. Short circuiting, for instance, not only reduces detention time, it results in pond dead areas which reduce the effective storage at the facility.



Configuration	Number of tanks, n
A	1.4
B	1.4
C	1.1
D	1.2
E	4.2
G	4.2
H	1.1
I	1.7
J	10
K	1.6
O	1.4
P	2.6
Q	2.4

Table D-1: Relationship between pond layout, hydraulic efficiency and the number of CSTR tanks. Layouts O and P include an island, G has 3 baffles and Q has a berm. Modified after Persson and Wittgren (2003), Persson (2000) and Persson et al. (1999).

Appendix E C-CALM documentation and applications

The following is a bibliography which documents the development and usage of C-CALM.

Model development reports

Semadeni-Davies, A. (2008a) C-CALM review of removal efficiencies for stormwater treatment options in New Zealand, NIWA client report prepared for Landcare Research Ltd.,

Semadeni-Davies, A. (2008b) C-CALM treatment modules: Models for Catchment Sediment Transport, Ponds and Raingardens, Niwa client report prepared for Landcare Research Ltd.

Semadeni-Davies, A. and Harper, S. (2008) Progress on the Development of C-CALM Performance Rules for Ponds, Wetlands and Raingardens. Addendum: Sensitivity Analysis, NIWA client report prepared for Landcare Research Ltd.

Harper, S., Semadeni-Davies, A. and Elliott, S. (2008) Progress on the Development of C-CALM Performance Rules for Ponds, Wetlands and Raingardens, NIWA client report prepared for Landcare Research Ltd.

Conference papers

Wadwha, S. and Semadeni-Davies, A. (2012) C-CALM: Catchment Contaminant Annual Loads Model. *ESRI International User Conference: Understanding Our World*, San Diego, CA, USA, July 23-27, 2012 (3rd Place Winner in Desktop Application category).

Moores, J. and Semadeni-Davies, A. (2011) Integrating a stormwater contaminant load model into a spatial decision support system for urban planning. *International Conference of the IWA Diffuse Pollution Specialist Group on: Diffuse Pollution and Eutrophication*, Rotorua, New Zealand, 18-23 September 2011.

Semadeni-Davies, A., Moores, J. and Altenberger, A. (2010) C-CALM development and application of a planning tool for stormwater management in New Zealand *17th Congress of the Asia and Pacific Division of the International Association of Hydraulic Engineering and Research incorporating the 7th International Urban Watershed Management Conference*, Auckland, New Zealand, 22-24 February, 2010.

Semadeni-Davies, A., Altenberger, A. and Wadhwa, S. (2009) C CALM – Catchment Contaminant Annual Loads Model. *NZWWA 6th South Pacific Stormwater Conference*, Auckland, New Zealand, May 2009.

Applications

Moores, J.; Semadeni-Davies, A.; McBride, G. and Swales, A. (2012) Quantifying contaminant sources in the Upper Whangarei Harbour catchment. Client Report prepared by NIWA for Northland Regional Council, NIWA Report: AKL2012-047

Vesely E.-T., Semadeni-Davies, A. and Simcock, R. (2009) Waiarohia catchment stormwater treatment modelling with C-CALM and COSTnz. Landcare Research Contract Report prepared for: Waitakere City Council.