The CLUES Project:
Tutorial manual for CLUES 2.0.6

NIWA Client Report: HAM2009–146
September 2009

NIWA Project: AGR08220

The CLUES Project:
Tutorial manual for CLUES 2.0.6

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Prepared for

Ministry of Agriculture and Forestry

NIWA Client Report: HAM2009–146
September 2009

NIWA Project: AGR08220

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1. Project background

The Ministry of Agriculture and Forestry (MAF), in association with the Ministry for the Environment (MfE), has engaged NIWA and five subcontractors (Lincoln Ventures, Harris Consulting, AgResearch, HortResearch[1], and Landcare Research) to develop a modelling system to assess the effects of land use change on water quality and socio-economic factors at a regional or national level. The system is called CLUES — Catchment Land Use for Environmental Sustainability.

CLUES has been developed as a tool for assessing the effects of land use and land use change on water quality at a minimum scale of sub-catchments (~10 km^2 and above). CLUES runs within a GIS platform (ArcGIS) and currently predicts loads, concentrations and yields of two nutrients (nitrogen and phosphorus), sediment loads and yields and a microbial health risk indicator (*E. coli*). In addition to these water quality parameters, CLUES has a socio-economic model to simulate the economic output from different land use types. Users are provided with the CLUES interface and geo-spatial data at national, regional, catchment and sub-catchment levels. Its terrain data is at 30 m resolution. The base areal unit of CLUES is the sub-catchment which comes from the NIWA River Environment Classification (REC) of the national stream and sub-catchment network[2]. Each sub-catchment is associated with a river reach which as a unique identifier (i.e., NZ reach number) — there are some 600,000 reaches in the REC. Predictions of the water quality and financial indicators given above can be made for any reach.

The CLUES catchment modelling framework allows users to easily develop and simulate the effects of land use change on stream water quality and integrates the following components:

- **SPARROW** (Spatially referenced regression on watershed attributes) — predicts annual average stream loads of total nitrogen, total phosphorus, sediment and *E. coli*. It includes extensive provisions for stream routing and loss processes. This modelling procedure was originally developed by the USGS (Smith et al. 1997) and has since been applied and modified in the New Zealand context, in extensive liaison with the developers. **SPARROW** has been applied to nitrogen and phosphorus in the Waikato (Alexander et al. 2002, by fitting models to Environment Waikato data) and subsequently to the whole New Zealand landscape (Elliott et al. 2005, by fitting models to data from NIWA's National Rivers Water Quality Monitoring Network). A

[1] Now Plant & Food Research
[2] http://www.niwa.co.nz/ncwr/rec

national model for *E. coli* is now available (Alexander & McBride in prep., obtained by fitting models to a national microbial water quality dataset reported by Till et al. 2008). The **SPARROW** sediment transport routines were assessed by Elliott et al. (2008) and simulations compared favourably with measured sediment load data.

- **SPASMO** (Soil Plant Atmosphere System Model, HortResearch)—calculates the nitrogen budget for five horticultural enterprise scenarios. Detailed simulations for many cases (combinations of crops, climate, fertiliser use) have been run (using a daily time step) to build look-up tables that CLUES accesses. It has been validated against data from grazed pasture (Rosen et al. 2004) and pasture treated with herbicide (Close et al. 2003, Sarmah et al. 2004).

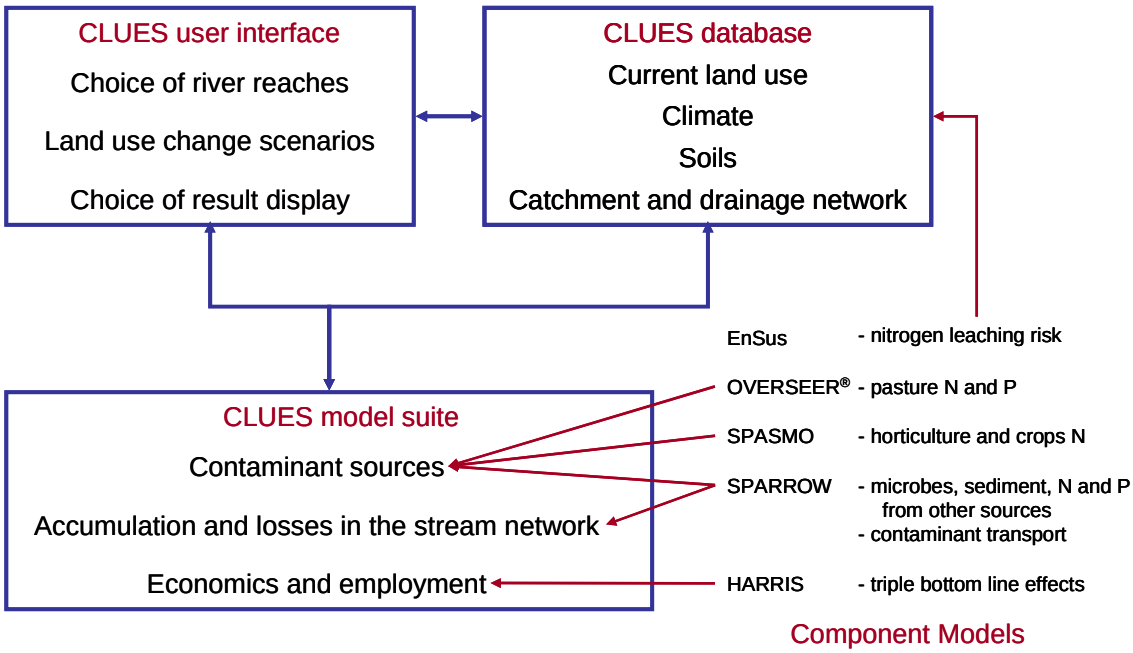
- **OVERSEER®** (AgResearch, Wheeler et al. 2006)—computes nutrient leaching for various land uses (dairy, sheep/beef lowland, sheep/beef hill country, sheep/beef high country, and deer). It provides annual average estimates of nitrogen losses from these land uses, given information on rainfall, regional rainfall, soil order, topography and fertiliser applications.

- **TBL** (Triple Bottom Line, Harris Consulting)—estimates economic output from different land use types (pasture, horticulture, forestry and cropping), in terms of Cash Farm Surplus (CFS), Total GDP and Total Employment from that land use, given as a function of output. The calculations are based on the MAF farm monitoring models.

- **EnSus** (Environmental Sustainability, Landcare Research)—provides maps of nitrogen leaching risk, used as an adjunct to interpretation of CLUES results. It is based on studies of nitrogen losses at national and regional scales (Hewitt and Stephens, 2002; Parfitt et al. 2006).

CLUES runs within a GIS platform (ArcGIS). It uses spatial datasets on current land use, soils (from the Land Resources Inventory Fundamental Soils Layer) and the NIWA REC (River Environment Classification) stream and sub-catchment network. The system includes data that is used by the component models, including runoff (derived from rainfall less evapotranspiration), slope, soil order, drainage classes, point sources and lakes. The current land use provided with CLUES was developed with extensive reference to the LCDB2 (Land Cover Database), AgriBase (AsureQuality Ltd), and LENZ (Land Environments of New Zealand) land use geo-databases. Considerable effort was expended, with Landcare Research, to ensure that the spatial data coverage was as accurate as possible.

The modelling framework, illustrated below, has been discussed by Woods et al. (2006).



Planned changes to CLUES as part of model development include:

- an ability to capture information at the farm scale
- local calibration of the underlying SPARROW model
- calculation of seasonal concentrations
- calculation of the effect of on-farm mitigation measures and land use intensification
- incorporation of a direct social component.

1.1 Manual layout

This manual is presented as a tutorial set out with worked examples. The examples use the files provided with the CLUES 2.0.6 CD for Waikato with Raglan Harbour as a case study and has been prepared using ArcMap v. 9.3. Users will need beginner to intermediate GIS skills to run CLUES 2.0.6 and intermediate to advanced skills for some applications such as editing land use layers for scenario creation.

1.2 CLUES database

The CLUES database contains spatial data which is provided as map layers within a regional map document (.mxd file) or incorporated into the model framework. For each river reach in REC, CLUES holds the following information:

- Reach identification number.
- Flow distance to the coast.
- Stream order
- Position in the stream network with respect to reaches up- and down-stream.
- Reach length
- Channel slope
- Whether the reach is part of a lake is a terminal reach.

Each reach has an associated sub-catchment which forms the basic spatial unit in CLUES. Data supplied for each sub-catchment includes:

- Sub-catchment boundaries
- Current land use with respect to the proportion of CLUES land cover types (derived from the MfE Land Cover Database V2—LCDB2);
- Estimated surface runoff (derived from rainfall and evapotranspiration); and
- Soil order and drainage class (from the Land Resource Inventory).

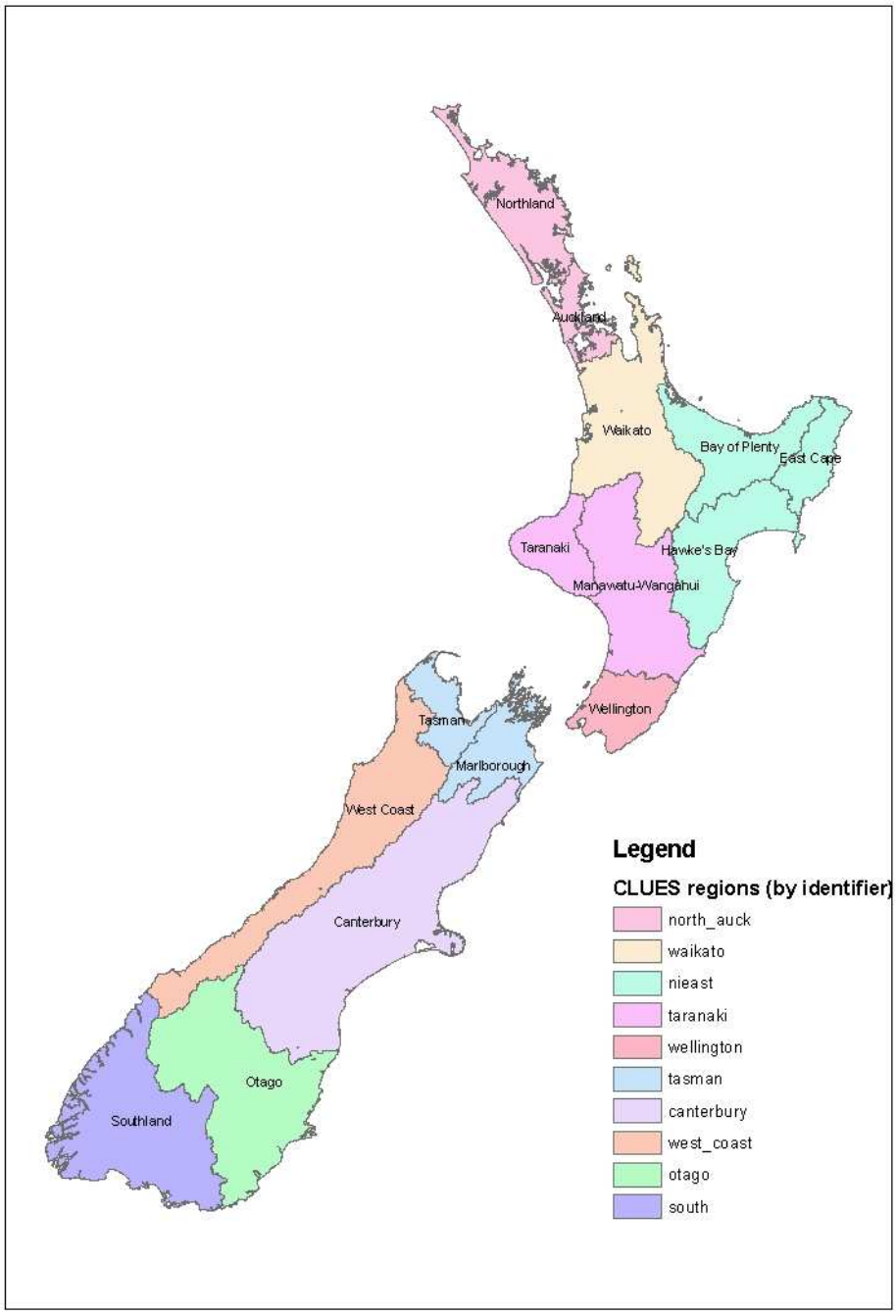
Other data include:

- Point sources such as piggeries, paper mills and sewage plants;
- Nitrogen leaching risk (i.e., from EnSus); and
- Lakes.

These data are provided either nationally or regionally as part of the CLUES system. There are 10 CLUES regions which cover the country, each regional CLUES folder holds all the data needed to run CLUES for that region. The regions and identifiers are:

- Northland / Auckland (north_auck)
- Waikato (waikato)
- Bay of Plenty / East Cape / Hawke's Bay (nieast)
- Taranaki / Manuwatu–Whanganui (taranaki)
- Wellington (wellington)
- Tasman (tasman)

- West Coast (west_coast)
- Canterbury(canterbury)
- Otago (otago)
- Southland (south)



1.3 CLUES land use types

CLUES simulates 22 land use types, these are listed below along with their field names in the order they appear in the CLUES *interactive sketch tool* drop-down menu and land use scenario layers (see Section 6)::

DAIRY	— dairying
SBHILL	— hill country sheep and beef
SBINTEN	— low land intensive sheep and beef
SBHIGH	— high country sheep and beef
DEER	— deer
OTHER_ANIM	— other types of farm animals
CROPS	— arable crops (e.g., maize and barley)
VEG	— market gardens, vegetables
BERRY	— berries
KIWI	— kiwifruit
SUM_FRUIT	— "summer" stone fruit (e.g., plums, peaches, nectarines)
TROP_FRUIT	— tropical fruit
PIP_FRUIT	— pip fruit (e.g., apples, pears)
FLOWERS	— flowers
VITI	— viticulture, vineyards
PLANT_FOR	— planted exotic forest, forestry
NAT_FOR	— native forest
SCRUB	— scrubland
URBAN	— urban areas
OTHER	— other land covers (e.g., ice, bare soil etc.)
TUSSOCK	— tussock
UNGR_PAST	— ungrazed pasture

These classifications were produced by Landcare Research Ltd. and are defined by Woods et al. (2006). New land use layers created for land use change simulations must have the land use fields in the same order as above in their respective attribute tables (see Sections 6.2 and 6.3).

1.4 Results generated

Results provided by CLUES are:

Water quality

- Nutrient loads (tonnes/year)—in-stream cumulative nitrogen and phosphorus loads for a particular river reach. That is, the load for that river reach and its up-stream tributaries
- Sediment load (kilo-tonnes/year)—in-stream cumulative load of total suspended solids (TSS) for a particular river reach
- *E. coli* loads (10^{15} or one "peta" of organisms/year) – in-stream cumulative load for a particular river reach
- Nutrient concentration (mg/m^3)—in-stream nitrogen and phosphorus median concentration for a particular river reach. Details on the calculation of concentration are given in Appendix One.
- Nutrient yields (kg/ha/year)—nitrogen and phosphorus load divided by the contributing area. Provided in two forms:
  Cumulative—the in-stream yield in a particular reach which represents the total yield for that reach and its up-stream tributaries.
  Generated—the yield generated by each specific sub-catchment. This information can be used to identify sources of nutrients.
- Generated Sediment yield (kg/ha/year)—yield of TSS generated by each specific sub-catchment. This information can be used to identify sources of sediments.
- Total nitrogen loss risk (scale from very low to very high)—the leaching risk for nitrogen based on land use from EnSus. This is displayed as a dockable raster window with pixel resolution of 100 metres.

Economic indicators

- GDP (gross domestic product, $/year)—an estimate of the total value arising from the farming, horticulture, and pine plantation land uses.
- FTE (full time equivalents)—an indication of total employment for farms where employment is work done by employees and self-employed persons.
- CFS (cash flow surplus)—this is the output from the land use after farm working expenses have been deducted, but before interest, leases, wages of management, and capital expenditure. CFS is used an indicator of on farm welfare. It should not be taken as a direct measure of on farm welfare.

More information on the Triple Bottom Line economic indicators can be found in Harris Consulting (2007).

E. coli is used for indexing the overall pathogenicity of microbial water contaminants, for which many pathogens may be present—albeit often only occasionally. Although the national freshwater microbiology programme (Till et al., 2008) also provided data on other indicators (spores and phages) and pathogens (*Campylobacter*, *Salmonella*, *Giardia* cysts, and *Cryptosporidium* oocysts), it is held that *E. coli* is the best choice for the purposes of the CLUES model objectives, not least because it is used in standards and guidelines for recreational water, drinking water, and shellfish flesh.

CLUES results are held in the *catchment* layer of the regional map document supplied with CLUES 2.0.6. Further information about this layer is given in Section 7.1 and the result fields are listed in Appendix Two.

1.5 Types of display

CLUES 2.0.6 allows the user to choose between a number of displays both to show the results of particular land use scenario simulations and to allow comparison between the default (current) land use scenario and changed land use. The types of display are illustrated with CLUES results for catchments draining to the south of Raglan Harbour in Waikato.

1.5.1 Maps

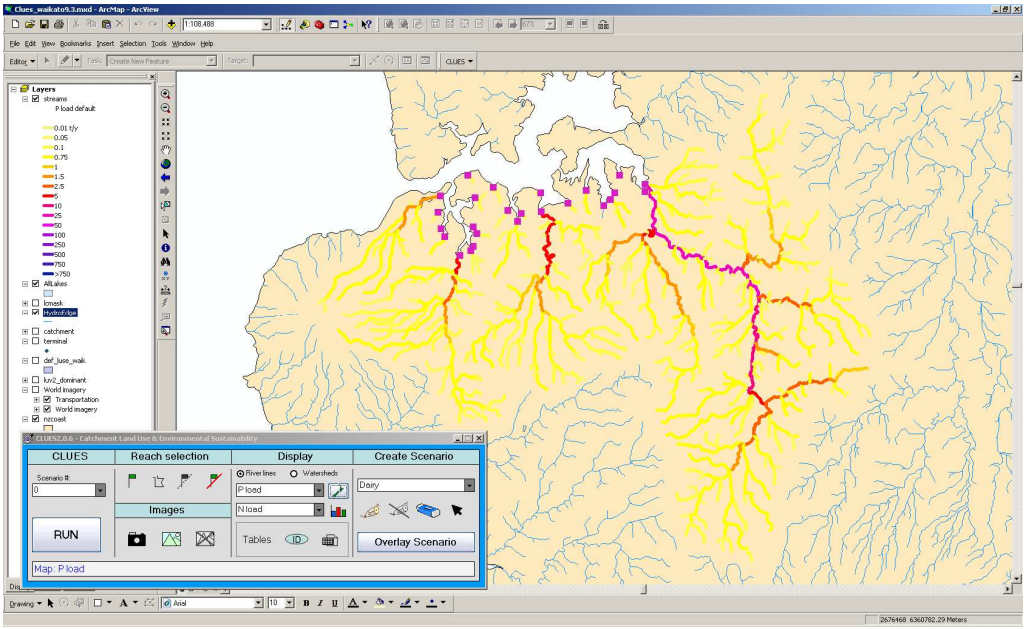
CLUES 2.0.6 displays model results in map format (Section 5.1) for the following:

- Nutrient loads (river lines or watershed option).
- Nutrient concentrations (river lines or watershed option).
- Sediment load (river lines or watershed option).
- Nutrient cumulative yield (river lines option).
- Nutrient generated yield (watershed option).
- Sediment generated yield (watershed option).
- *E. coli* load (river lines or watershed option).
- Total nitrogen loss risk (dockable window raster map).

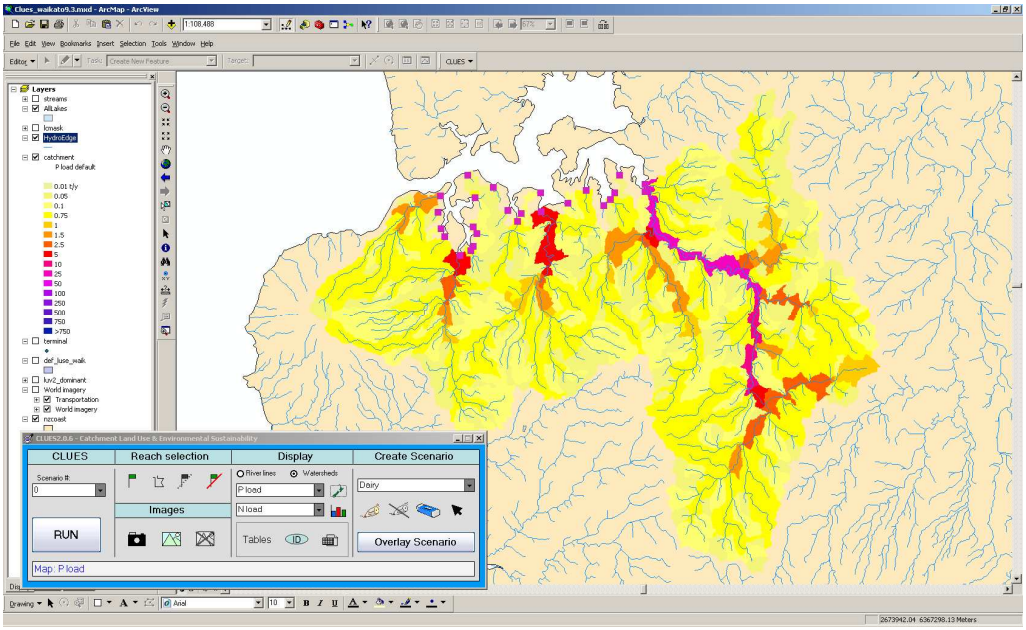
In addition to the result layers, CLUES 2.0.6 is provided with reference layers for the NZ coastline, lake boundaries and ESRI online aerial imagery.

Example of map displays of results (P load)

River Lines



Watershed



1.5.2 Bar charts

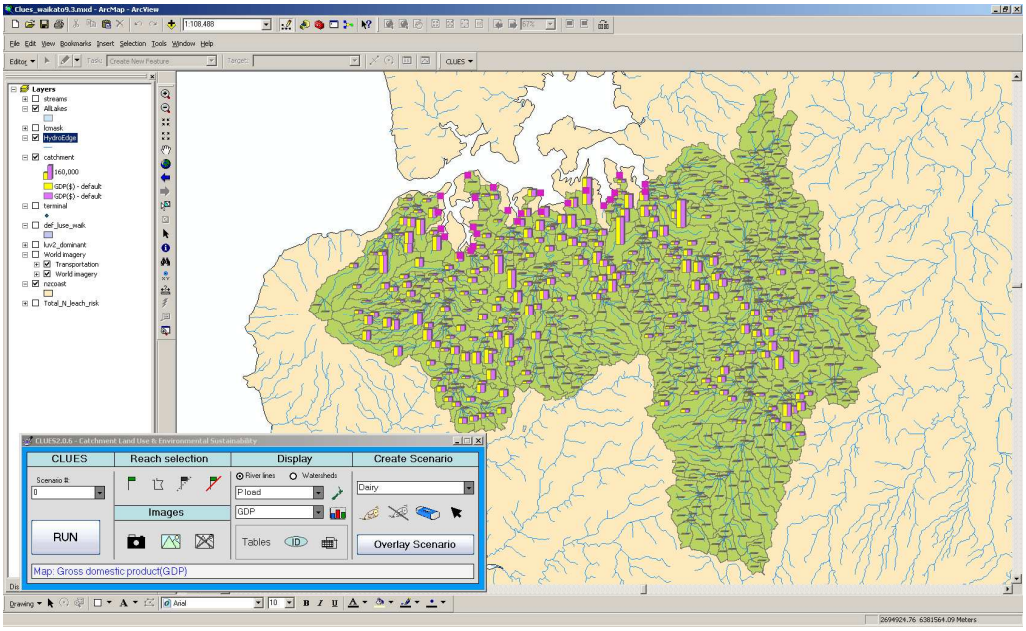
Bar charts (Sections 5.2 and 6.4.2) allow quick comparisons between the default land use and simulations made with changed land use scenarios. The primary function of bar charts is to provide a geo-visualisation tool which shows the impacts of land use change compared to the default land use. Charts available, in the order they appear in the *Chart variable* drop-down menu, are:

- GDP
- FTE
- CFS
- Nutrient loads
- Nutrient concentrations
- Sediment load
- Nutrient generated yields
- Sediment generated yields
- Nutrient and E. coli loads

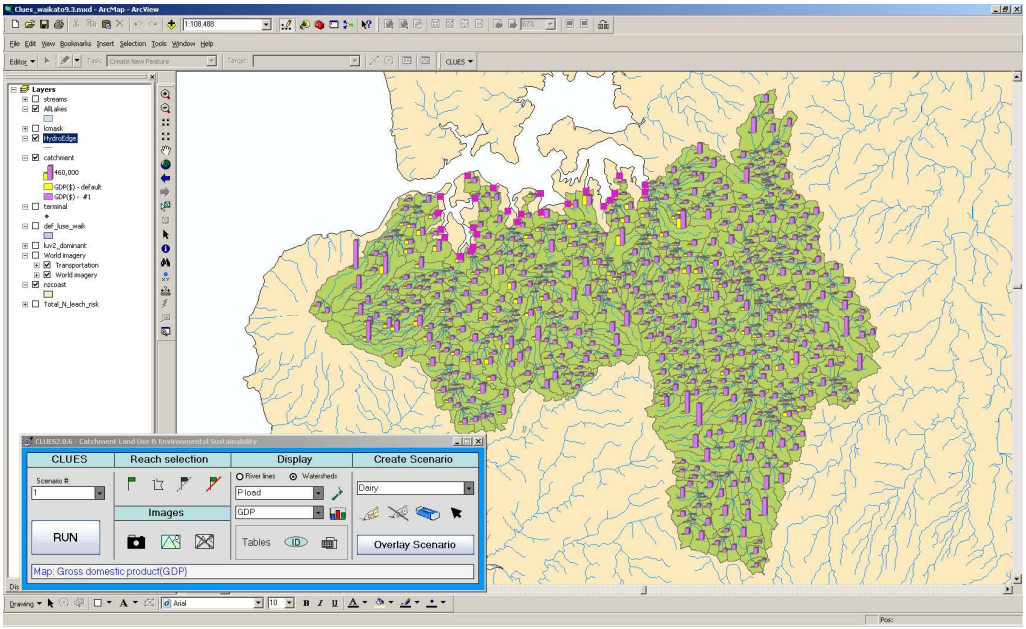
If no new land use scenario has been simulated, both bars of the chart relate to the default. If new land use scenarios have been simulated, the results for the default and the selected scenario are plotted together.

Example outputs for bar charts (GDP)

Default



New land use scenario



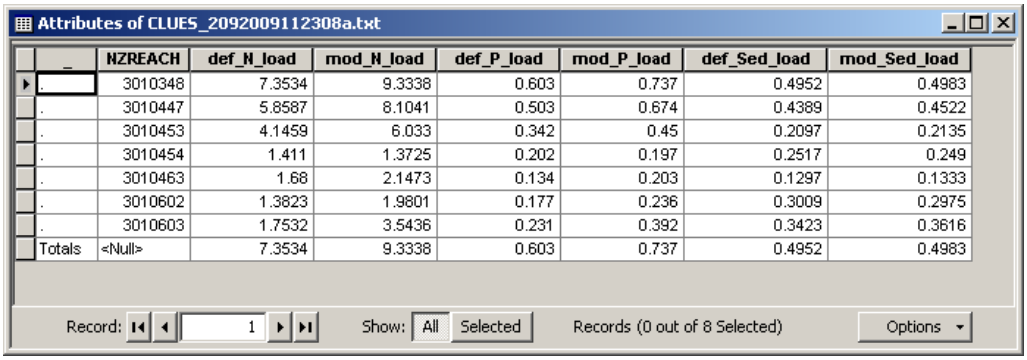
1.5.3 Tables

CLUES 2.0.6 provides two types of table (Sections 5.3 and 6.4.3) that can be used to summarise and compare results for individual river reaches (sub-catchment) and for all the river reaches selected in a model run. If new land use scenarios have been simulated, the results for the default and the selected scenario appear in the tables.

Results for selected sub-catchment; default land use scenario.

N /P Loads, Triple Bottom Output	
AREA_HA	117.720
CFS($) - default	29794.699
FTE - default	0.501
GDP($) - default	44524.898
N Conc(mg/m3) - default	900.368
N cum.yield(kg/ha/y)-default	14.271
N gen.yield(kg/ha/y)-default	17.512
N load(t/y) - default	1.680
P Conc(mg/m3) - default	103.219
P cum.yield(kg/ha/y)-default	1.138
P gen.yield(kg/ha/y)-default	1.200
P load(t/y) - default	0.134
peta E.coli per year-default	0.020
SED gen.yield(kg/ha/y)-default	1.102
SED load(kt/y) - default	0.130

Summary showing results for default and changed land use scenarios for all reaches simulated.



Attributes of CLUES_2092009112308a.txt

_	NZREACH	def_N_load	mod_N_load	def_P_load	mod_P_load	def_Sed_load	mod_Sed_load
.	3010348	7.3534	9.3338	0.603	0.737	0.4952	0.4983
.	3010447	5.8587	8.1041	0.503	0.674	0.4389	0.4522
.	3010453	4.1459	6.033	0.342	0.45	0.2097	0.2135
.	3010454	1.411	1.3725	0.202	0.197	0.2517	0.249
.	3010463	1.68	2.1473	0.134	0.203	0.1297	0.1333
.	3010602	1.3823	1.9801	0.177	0.236	0.3009	0.2975
.	3010603	1.7532	3.5436	0.231	0.392	0.3423	0.3616
Totals	<Null>	7.3534	9.3338	0.603	0.737	0.4952	0.4983

Record: 1 Show: All Selected Records (0 out of 8 Selected) Options

2. Installing CLUES

2.1 System requirements

You will need the following to use CLUES 2.0.6:

- ArcGIS v. 9.3 (ArcMap or ArcView).
- 1 GB RAM.
- Web connection (for display of ESRI World Imagery layers)
- Windows XP (the programme has not been tested with other versions of Windows but will work as long as ArcGIS is operational).
- Administrative rights.

2.2 Installation

CLUES 2.0.6 is available on CD or file download from NIWA. Each CD contains all the files needed to set-up and run CLUES 2.0.6 for a particular region in a zipped format. These installation instructions are based on Windows XP. To install CLUES 2.0.6:

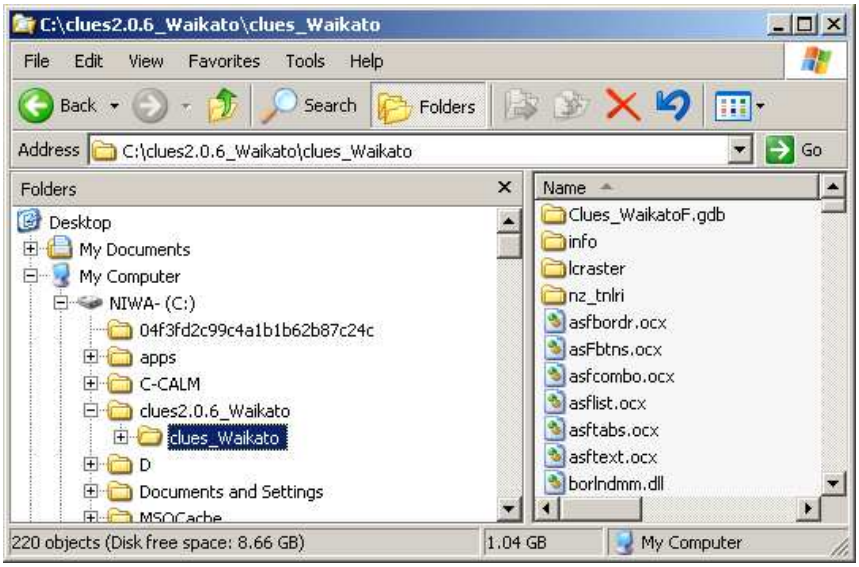
1. Quit ArcGIS.

2. Deregister any older versions of CLUES using the instructions in Section 2.3.

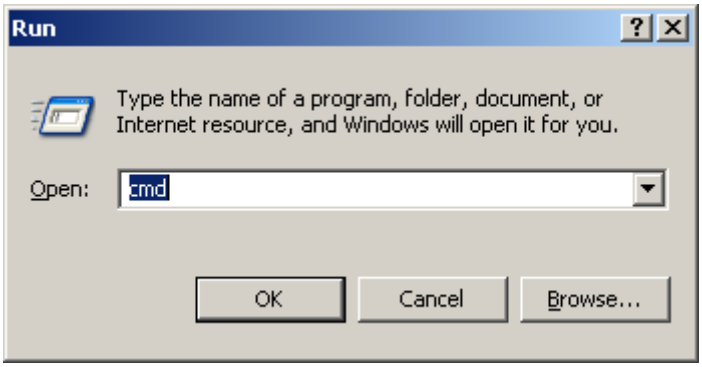
3. Extract the CLUES2.0.6.zip folder for your region into the root directory your local hard drive (c-drive). The local drive is recommended as:

    - Running ArcGIS / CLUES over a network can take time; and

    - CLUES can have problems registering if the directory pathway has spaces which can occur in Windows locations such as “Program Files” (tip: use an underscore “_” character for spaces when naming layers and folders for use in ArcGIS).



4. Open the DOS command line window by clicking *RUN* under the START menu in Windows and selecting *cmd*.

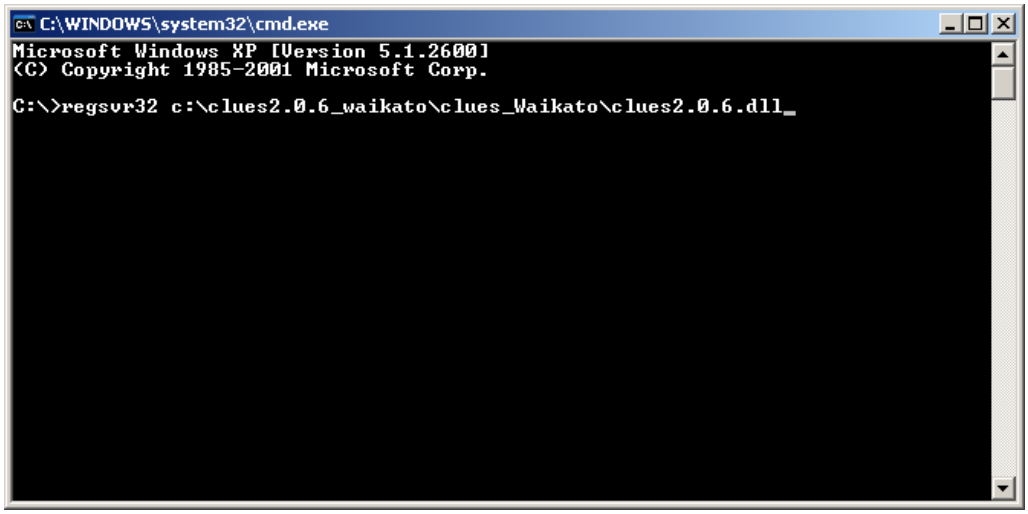


5. Type the following command into DOS to register the CLUES 2.0.6 dynamic link library (clues2.0.6.dll):

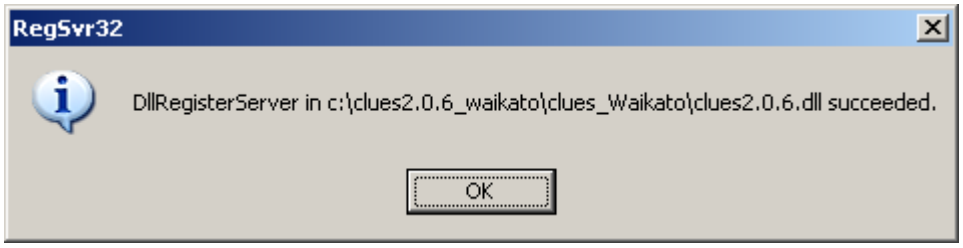
   regsvr32 directory_path\clues2.0.6.dll

   where directory_path is the location of the regional CLUES folder, in this example:

   regsvr32 c:\clues2.0.6_Waikato\clues_waikato\clues2.0.6.dll

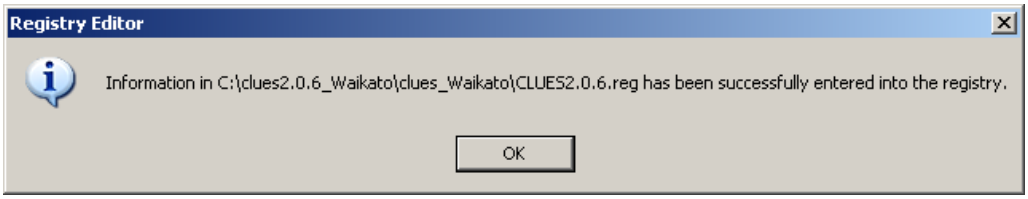


6. Click *OK* at the prompt.



7. In Windows Explorer, open the Clues regional folder and double click on the file CLUES2.0.6.reg. Click *Yes* at the prompt.

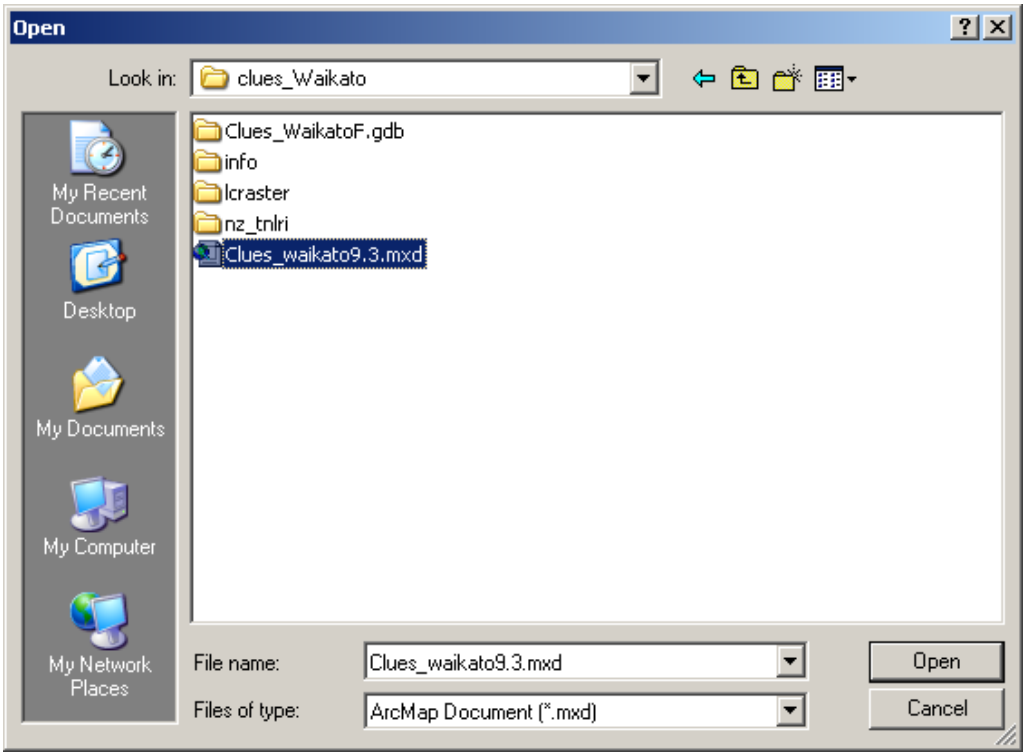
8. Click *OK* at the prompt to confirm registration.



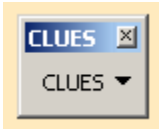
CLUES 2.0.6 is now registered and is available for use in ArcGIS.

Provided the regional folder is not moved or deleted from the directory, you will not need to re-register CLUES 2.0.6 should you wish to simulate water quality with a different regional database.

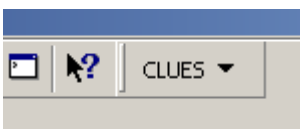
9. Start ArcGIS and browse to open the regional map document provided with CLUES 2.0.6 (for Waikato: Clues_waikato9.3.mxd).



The CLUES toolbar should be automatically displayed by ArcGIS:

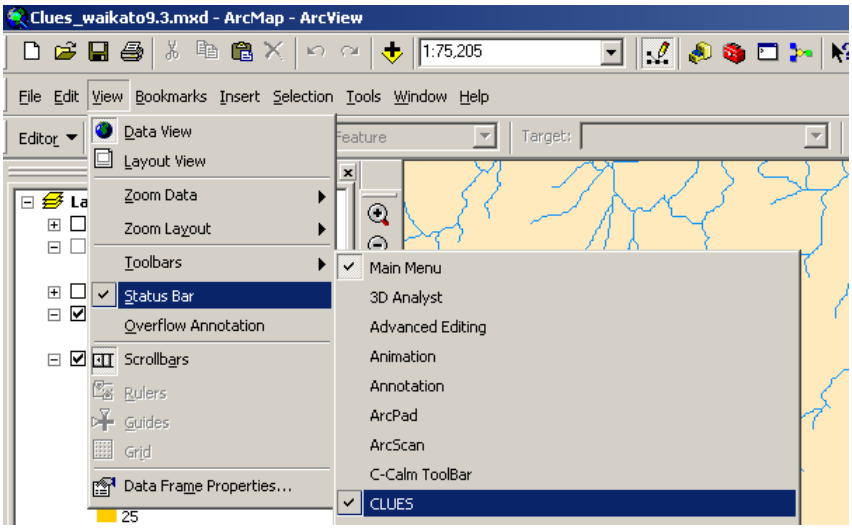


or

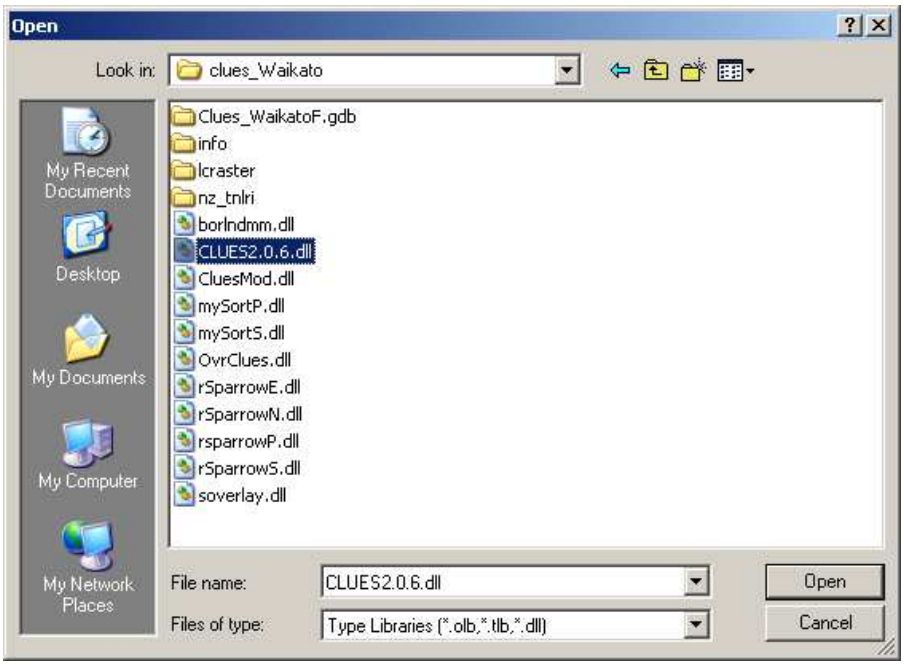


TROUBLE SHOOTING: I can't see the CLUES toolbar.

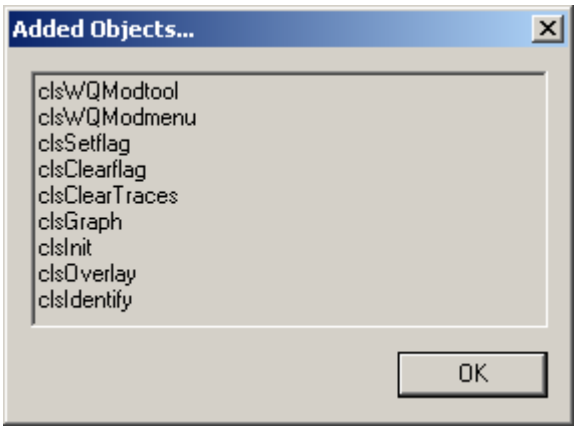
If the CLUES toolbar does not appear on opening ArcMap, look under *Toolbars* in the *View* menu to check whether CLUES is available but has not been automatically displayed by ArcMap. If CLUES is listed, select and click to bring up the toolbar.



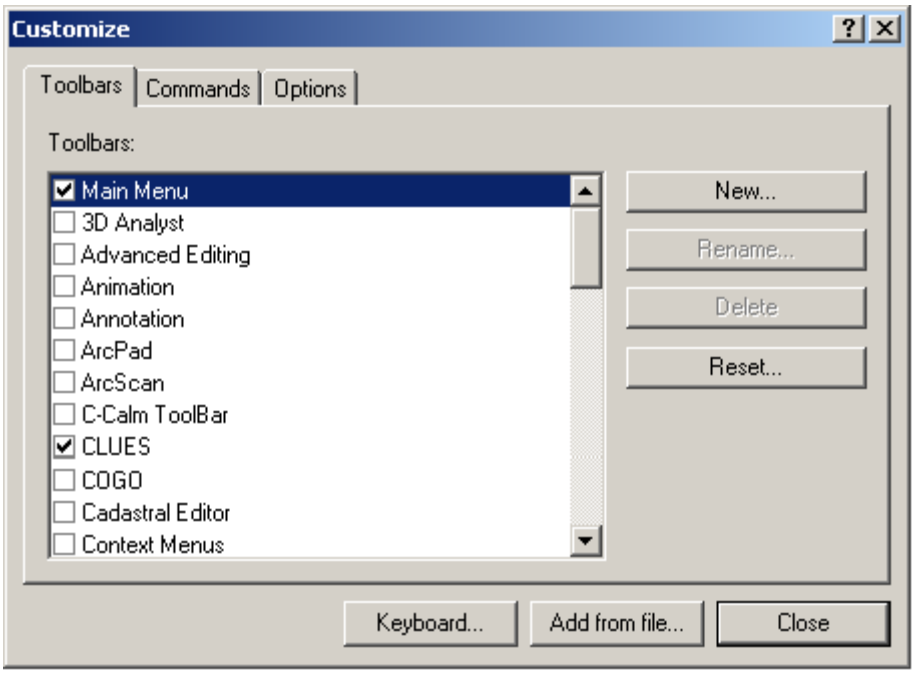
If the CLUES toolbar is not available, click *Customize* under the *Toolbars* menu and then the *Add from File* button to bring up the *Open* window. Browse to your CLUES 2.0.6 regional directory and select CLUES2.0.6.dll.



Click *OK* at the prompt.



CLUES should now appear in the *Customize* window, check the box to add CLUES to the toolbar.



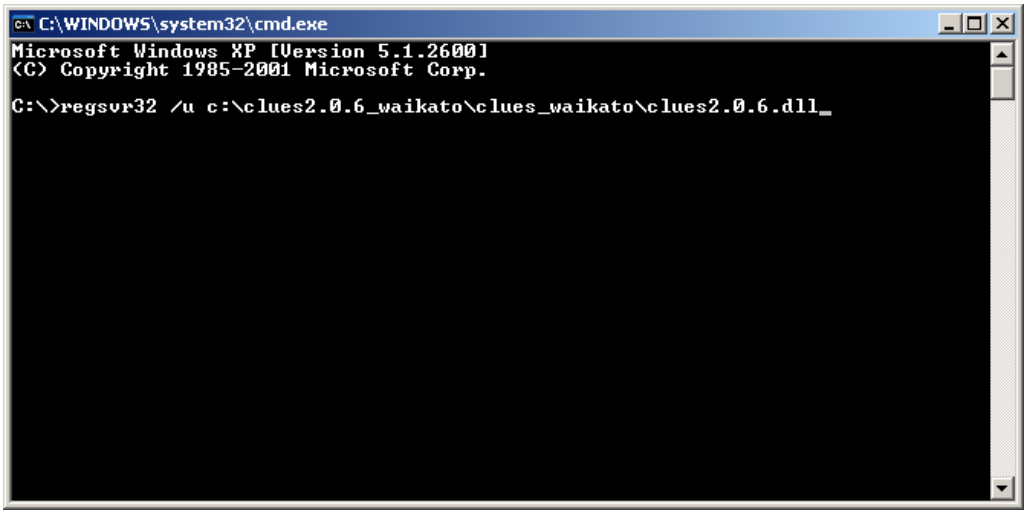
2.3 Removing CLUES

CLUES 2.0.6 can be removed by quitting ArcGIS and deregistering CLUES2.0.6.dll using the following command in DOS and clicking *OK* at the prompt:

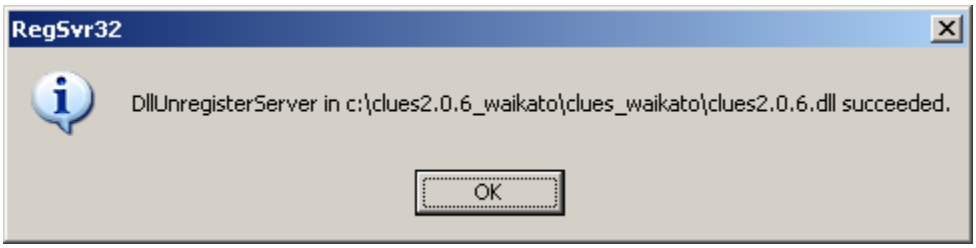
regsvr32 /u directory_pathway\clues2.0.6.dll

where directory_pathway is the location of CLUES2.0.6.dll, in this example:

regsvr32 /u c:\clues2.0.6_waikato\clues_waikato\clues2.0.6.dll



Click *OK* at the prompt.

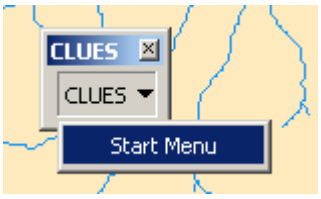


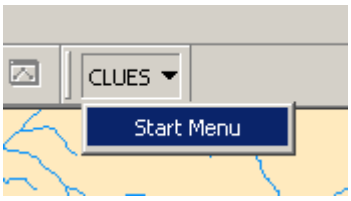
The same command must be used to deregister earlier versions of CLUES prior to installation of CLUES 2.0.6—to do this, replace the directory pathway and the CLUES dll file name with those of the earlier version.

3. The CLUES Interface

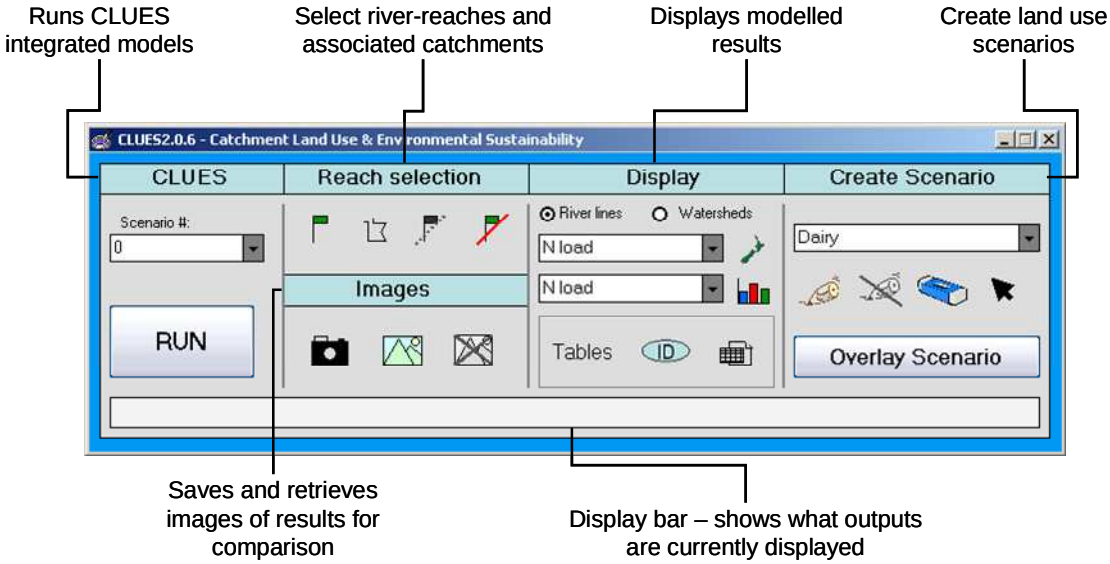
3.1 CLUES 2.0.6 toolbox

Once CLUES 2.0.6 has been installed and the regional map document supplied with CLUES opened (see Section 4.1), click Start menu on the CLUES toolbar to display the CLUES toolbox



or


The toolbox is separated into five sections relating to different CLUES functions:

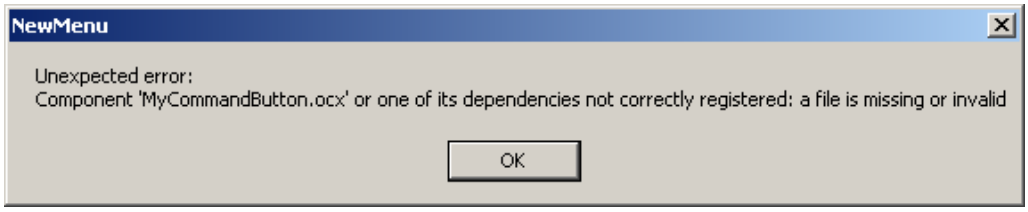


The toolbox can be moved by clicking the title bar and dragging. There are also standard Windows buttons for minimising or closing the toolbox at the top right corner of the title bar.

TROUBLE SHOOTING: I get this error message when I try to display the toolbar.

Registration was not completed; make sure you have double clicked on CLUES2.0.6.reg in your CLUES regional folder.

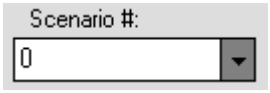
TROUBLE SHOOTING: I get this error message when I try to display the toolbar.



This error message does not affect CLUES and occurs on some PCs when CLUES is first registered. Click *OK* and then try to display CLUES again. The CLUES toolbar should appear from now on without problem.

3.2 CLUES tools

Tool-tips are displayed when the cursor is positioned above the buttons and drop-down menus. CLUES tools are as follows:

CLUES tools	
	*Scenario* drop-down menu Selects the land use scenario to be simulated. Up to five land use scenarios can be stored.
	*Run* button Runs the CLUES 2.0.6 model framework
Reach Selection tools	
	*Flag* icon Selects single or multiple river reaches. The icon brings up a flag cursor which, when clicked near a river reach, flags the reach and its tributaries. Clicking at the river outlet (terminal reach) will select the entire catchment.
	*Catchment selection polygon* icon Selects multiple catchments. The icon brings up a polygon tool which selects all catchments with their terminal reach within the polygon.
	NOT YET OPERATIONAL. Removes selected reaches sequentially. Planned for CLUES 3.
	*Deselect river reaches* icon Deletes all selected catchments and river reaches.
Images tools	
	*Camera* icon Creates a geo-referenced tiff image of the displayed map.
	*Retrieve image* icon Displays saved tiff files.
	NOT YET OPERATIONAL. Removes save images from the map document. Planned for CLUES 3.

Display tools	
	*Map type* radio buttons (River lines or Watersheds) *Map variable* drop-down menu *Map* icon The *Map* icon displays the variable selected in the drop down menu for the modelled area. Maps available are: N and P loads N and P concentrations Sediment load N and P yields (cumulative and generated) Sediment yield (generated) *E. coli* load Total nitrogen loss risk (as a dockable window) River lines displays results by colouring the stream network. The legend is under the *stream*s layer. Watersheds displays results by shading sub-catchments. The legend is under the *catchment* layer.
	*Chart variable* drop-down menu *Chart* icon The *Chart* icon displays results as bar charts on the map layer. The legend is under the *catchment* layer. Charts available are: GDP FTE CFS N and P loads N and P concentrations Sediment load N and P generated yields Sediment generated yield N leaching *E. coli* loads
	*Tables* *Identify sub-catchment* icon *Modelled area summary* icon The *ID* icon displays results for a selected sub-catchment. The *modelled area summary* icon displays modelled N loads for all the river reaches modelled for the default and current scenario model runs.

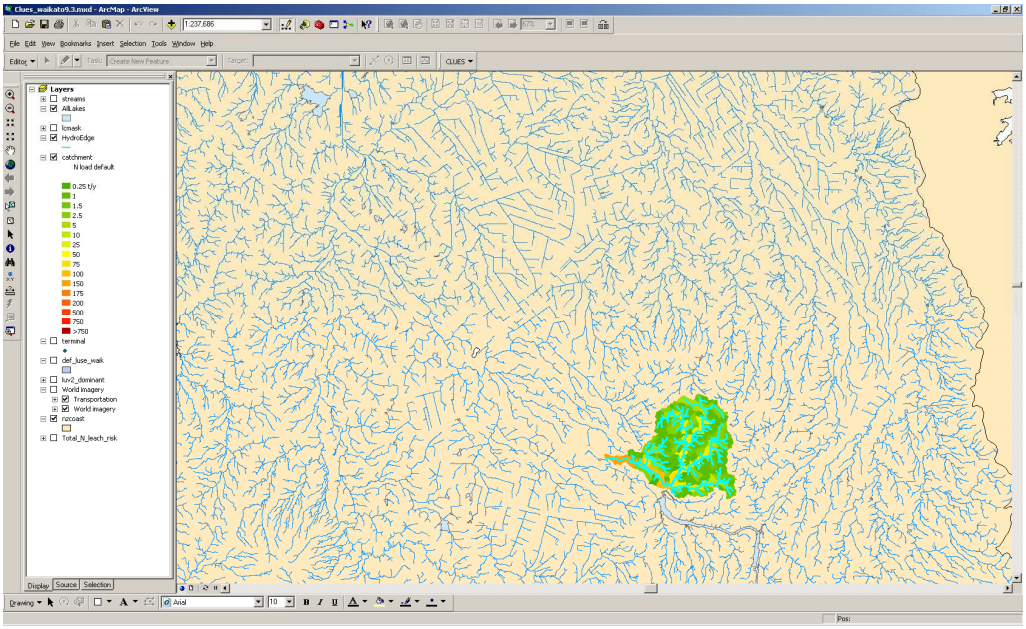
Create Scenario tools	
	*Land use* drop-down menu Allows selection of land use overlay polygon
	*Draw land use polygon* icon Draws a land use overlay polygon.
	NOT YET OPERATIONAL. Removes land use change overlay polygons sequentially. Planned for CLUES 3.
	*Eraser* icon Erases all land use overlay polygons.
	*Cursor reset* icon Resets cursor to a pointer.
	*Overlay Scenario* button Brings up the create new scenario overlay window

4. Basic functions

4.1 Getting started

1. Follow the instructions above to register CLUES 2.0.6 and start ArcInfo or ArcView v. 9.3.

2. Browse to your regional folder and open the map document supplied (the Waikato region has been used for this manual; i.e., Clues_waikato9.3.mxd). You will find that CLUES has already been run for a selected river reach, this has been done as part of CLUES testing.

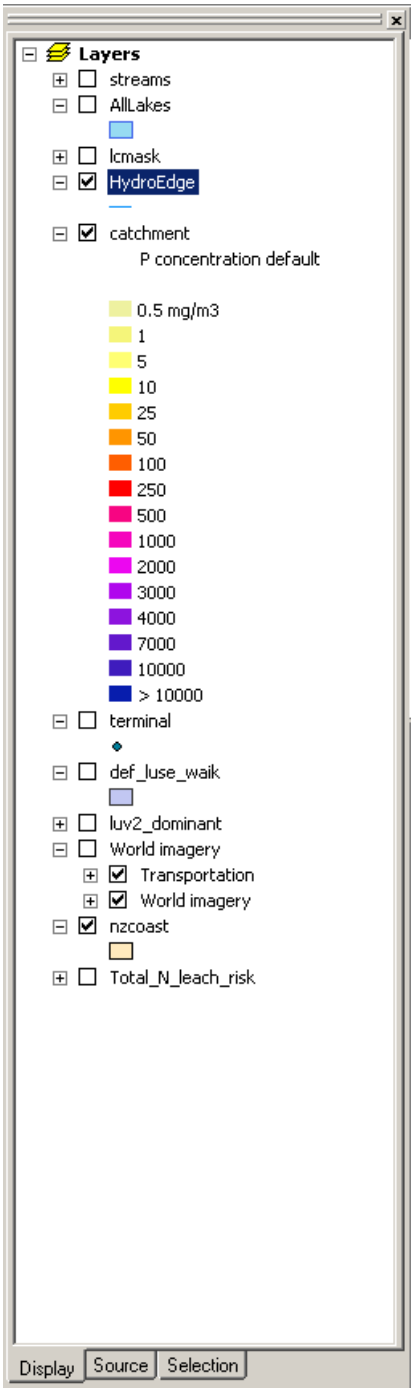


3. The table of contents (*TOC*) window should be open with the *Display* tab selected (see over page). Layers are displayed if their respective check boxes are ticked ☑. Legends can be displayed or hidden by expanding (+) or the minimising (-) the layer. Layers are drawn on the map following the *TOC* hierarchy with the upper layers overlaying those below.

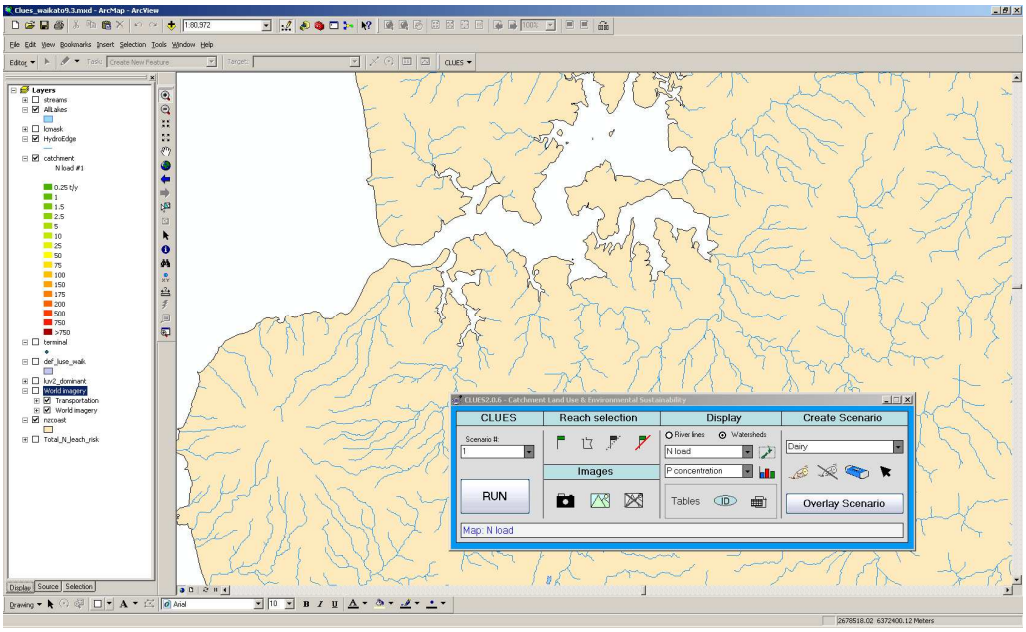
4. Pan and zoom the GIS display to your area of interest (here Raglan Harbour) using the standard ArcGIS tools:  pan,  zoom in and,  zoom out.

5. Click Start Menu under the CLUES toolbar to open the CLUES 2.0.6 toolbox (see Section 3.1 for an overview of the toolbox).

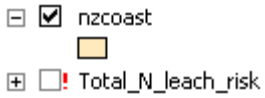
CLUES layers

TOC	Layer	Description
	streams	Displays model results for the selected river reaches and tributaries. Automatically displayed when river lines are mapped.
	AllLakes	Displays lakes larger than 1 ha in surface area. Manual display.
	lcmask	Interactive sketch overlay polygon layer. Manual display.
	HydroEdge	Defines stream network for tracing nutrients upstream. Automatic display.
	catchment	Displays model results for the selected river reach and sub-catchment(s). Automatically displayed for watershed maps and bar charts.
	terminal	Terminal nodes for stream network –used to trace catchments from coastal outlets. Manual display.
	def_luse_region e.g., def_luse_waik	Mock-up default land use layer supplied for land use scenario creation. The actual default land use database is not available to users. Manual display.
	luv2_dominant	Reference layer showing dominant land use used in preparation of the default land use database. Manual display.
	World imagery	Link to ESRI reference layers showing aerial images and major transport routes and airports. Manual display.
	nzcoast	Displays coastline. Can be replaced by other background layers without affecting model results. Automatic display.
	Total_N_leach_risk	EnSus total nitrogen loss risk based on soils. This layer is in raster format and is masked by the *nzcoast* layer. It can be displayed as a dockable window (Section 5.1.3). Manual display.


CLUES
Start Menu


CLUES
Reach selection
Display
Create Scenario
Images
RUN
Overlay Scenario
Map: N load

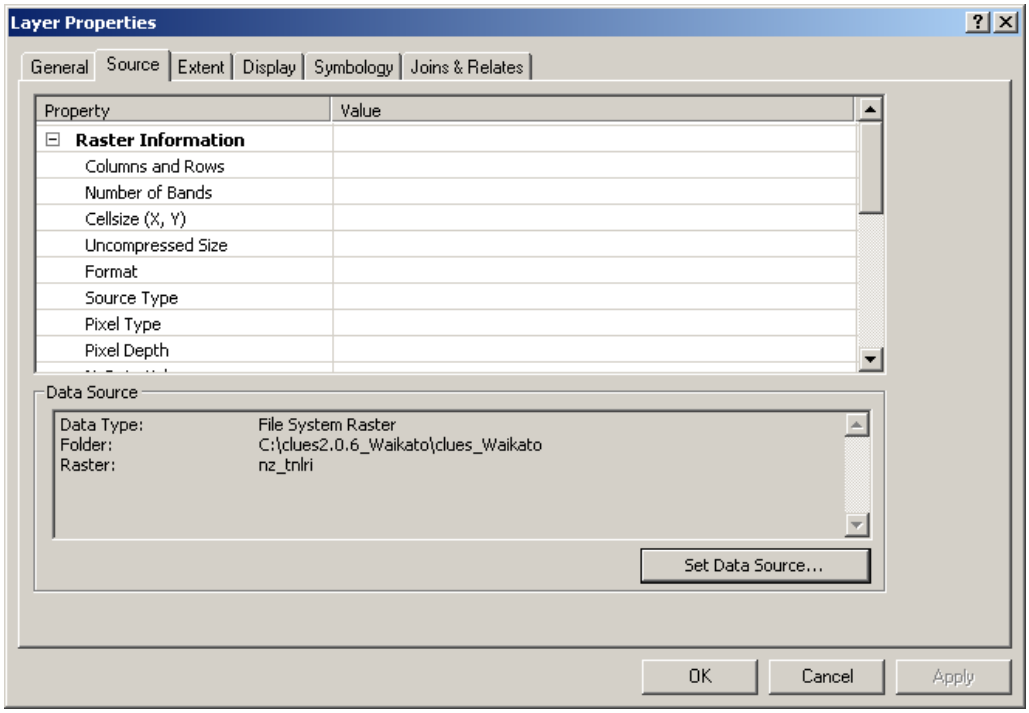
TROUBLE SHOOTING: one of the layers has a red exclamation mark (!) next to it in the *TOC* and will not let me check it for display.



ArcMap cannot not find the layer—this could be caused by the directory pathway for the layer being incorrectly recorded or failing to update. It can also mean that the layer was not copied into the CLUES regional directory you are working with.

1. Right click on the layer name in the *TOC* and select *Properties* to bring up the *Layer Properties* dialogue box and click on the *Source* tab.

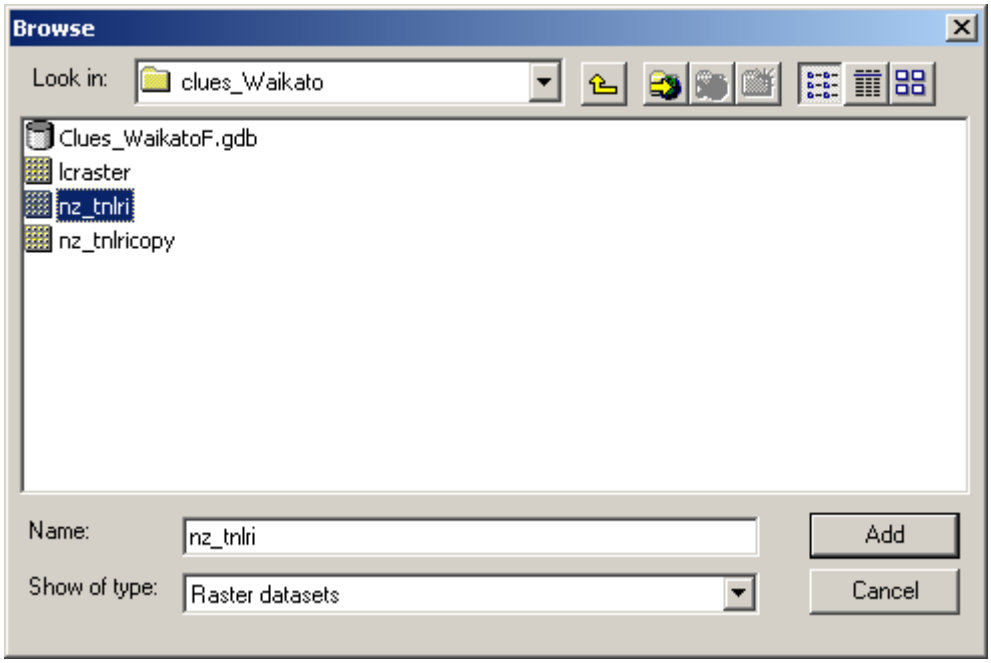
2. Make a note the source file and its location (in the example below, the layer name is nz_tnlri and the location is the regional CLUES folder for Waikato).



3. Click on the *Set Data Source* button and browse to your CLUES folder. Select the correct file. Click the *Add* button to reconnect the layer.

   NOTE: if you know the source file and location, you can open the *Set Data*

Source button directly by left clicking the layer in the *TOC*.



4. Click *OK* in the *Layer Properties* dialogue box to finalise the connection. The layer should now be available for display in the *TOC*.

5. If the layer is not listed in the CLUES folder, check whether the layer is in the zipped files for your region but was not extracted for some reason. Re-extract if necessary.

4.2 Selecting river reaches

CLUES 2.0.6 allows river reaches and their associated sub-catchments to be selected in three ways:

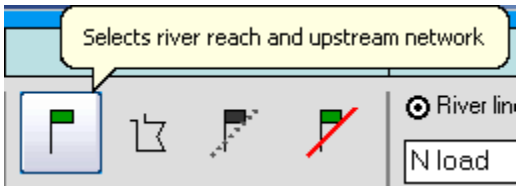
- single river start reaches
- multiple river start reaches, and
- multiple terminal reaches (i.e., catchments)

4.2.1 Single and multiple river start reaches

The CLUES *Flag* tool selects river reaches and associated sub-catchments upstream of the selection point or start reach. If the terminal reach (i.e., at the coastal mouth of the selected stream) is clicked, the entire catchment with all associated tributaries and sub-catchments will be selected.

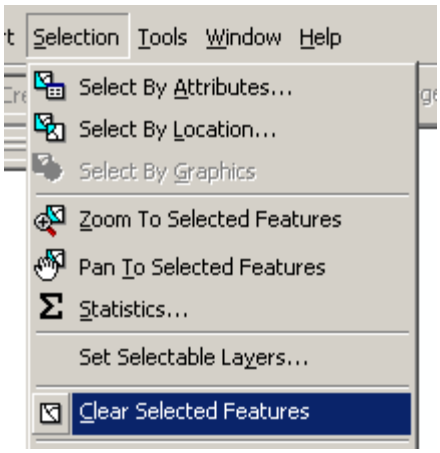
For this example, several river reaches located to the south of Raglan Harbour are selected in turn and as a group.

1. Click the *Flag* icon under the *Reach selection* tools, the cursor will change into a flag accordingly.

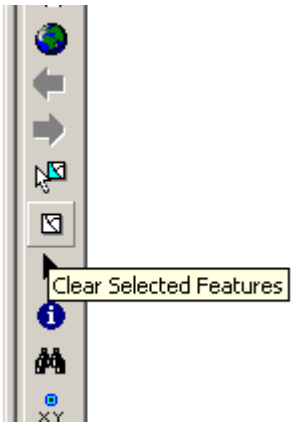


2. Place the flag on or near a river reach. Clicking will select the reach and upstream tributaries. The flag will snap to the nearest reach and a red tag will be placed at the selection point.

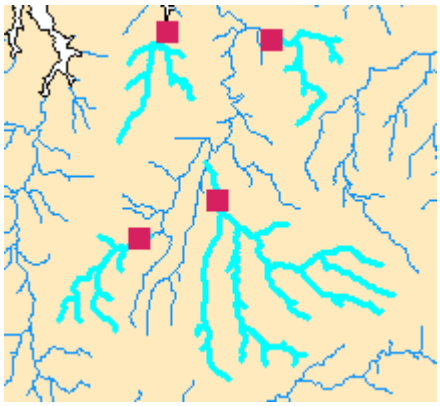
NOTE, ArcGIS will highlight the selected stream network (light blue is default selection colour above). This highlight can be removed without deselecting the stream network to be simulated in CLUES 2.0.6 using the *Clear Selected Features* command under the ArcGIS *Selection* menu or by clicking the *Clear Selected Features* icon on the Tools toolbar.



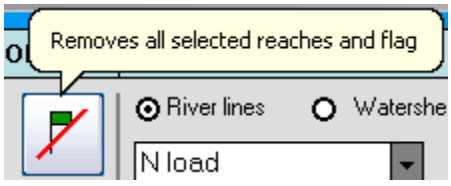
or



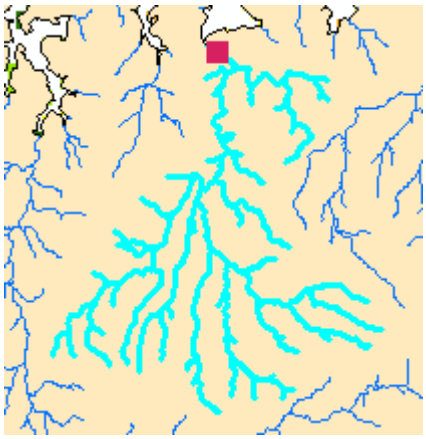
3. Multiple selections can be made by clicking other reaches.



4. The selected river reach or reaches can be removed by clicking the *Remove tags* icon under the *Reach selection* tools.



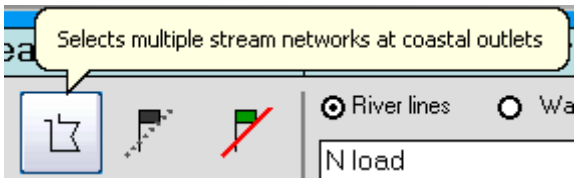
5. Clicking the flag at the coastal or terminal reach of a stream will trace upstream to select the entire catchment.



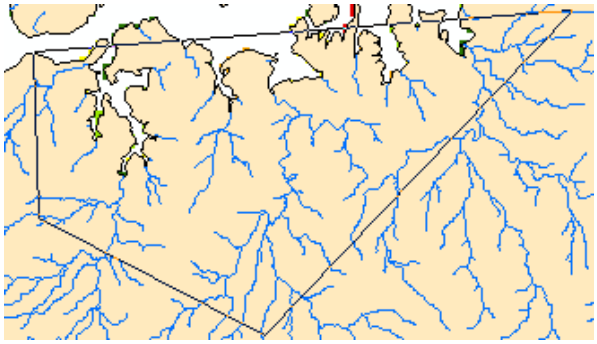
4.2.2 Terminal reaches

CLUES 2.0.6 allows multiple selection of coastal outlet or terminal reaches to select entire river catchments. Drawing a terminal reach selection polygon enables fast selection of streams flowing into coastal receiving environments. In this example, contributing catchments to the south of Raglan Harbour will be selected as a group.

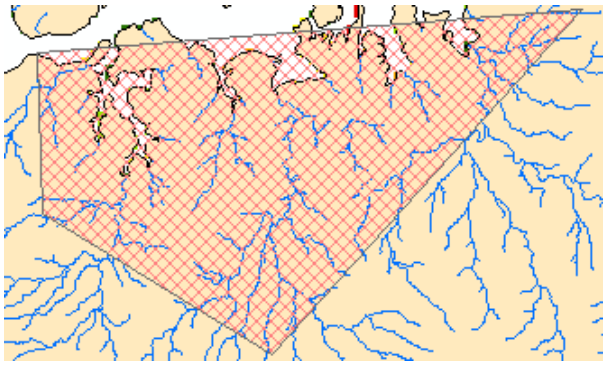
1. Click the *Catchment polygon* icon under the Reach selection tools. The cursor will change into a hand with crosshair.



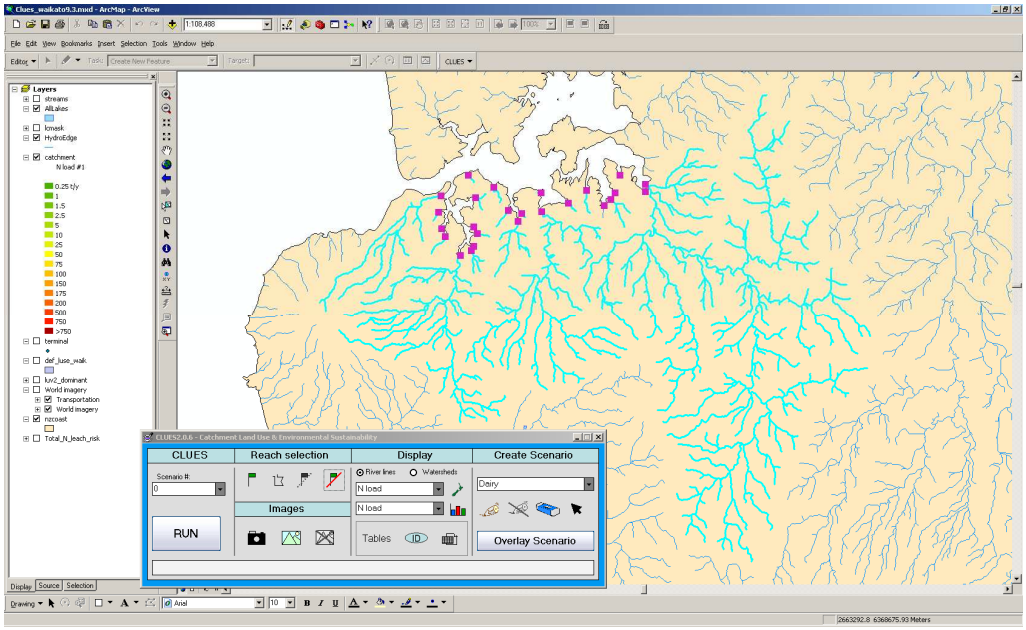
2. Position the cursor near the coastal reaches to be selected. Click and drag to create a selection polygon—vertices are created at each click position.



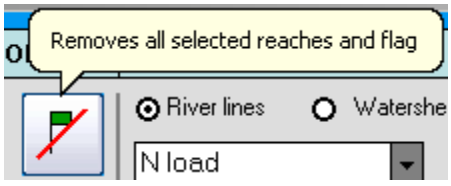
Double click to complete the terminal reach selection polygon.



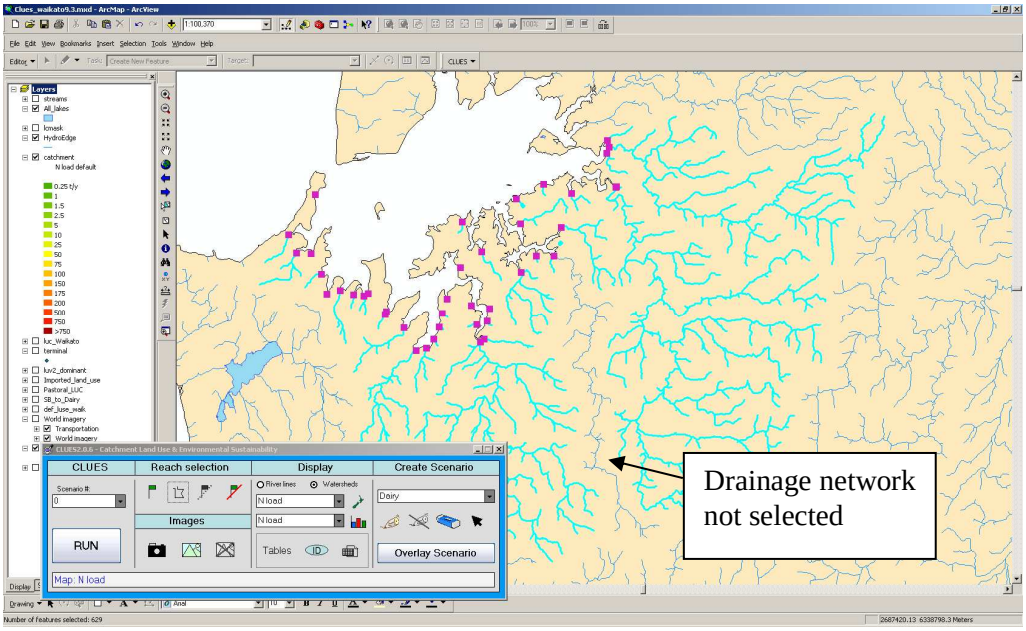
3. All catchments with a terminal reach in the polygon will be selected and their terminal reaches tagged with a cerise tag.



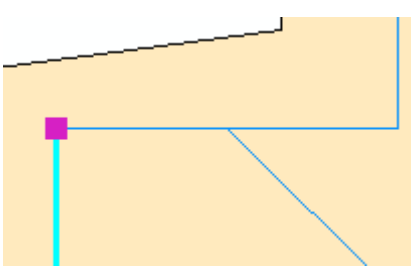
6. The selected river reach or reaches can be removed by clicking the *Remove tags* icon under the *Reach selection* tools.



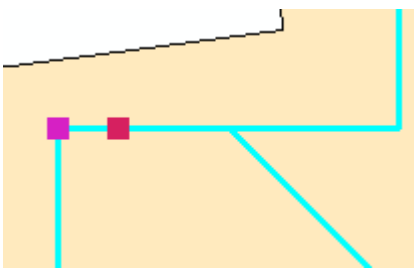
TROUBLE SHOOTING: I drew a polygon around a coastal area but CLUES did not include all the catchments in my selection.



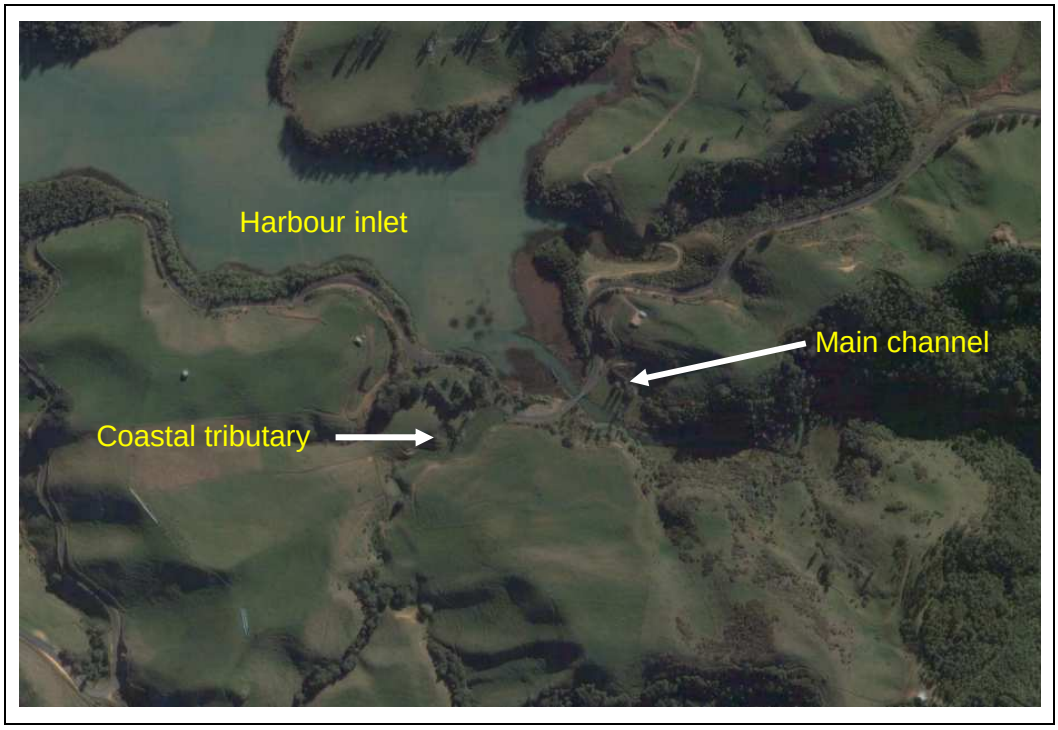
The CLUES stream network is derived from the REC river reach database. Catchments are composed of a series of linked river reaches which define the drainage network. REC data includes stream order,, distance to sea, the reach's position in the stream network, and whether the reach is terminal / coastal. This reach information is held for each region in the regional *HydroEdge* layer. Nodes for terminal reaches are stored as points in the *terminal* layer. REC also holds data on sub-catchments in the *catchment* layer. Sometimes, terminal reaches may be incorrectly assigned or left out of the river reach sequence for a stream network. Similarly, links between coastal reaches draining to the same point may not be recorded. In the example above from Kawhia Harbour, the terminal node has been assigned to a tributary of the main stream which joins at the same inlet of the harbour, however, the two coastal reaches are not linked in the REC so that only the tributary has been selected by CLUES. If this happens, tag the coastal reach manually using the *Flag* tool.



to



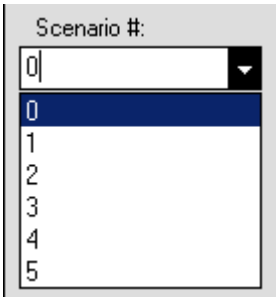
Note the tags have different colours, cerise for terminal reach selection using the polygon tool and red for reach selection using the flag tool.



4.3 Running the model

Once a river reach selection has been made, CLUES is ready to run. Each CLUES 2.0.6 run for a particular land use scenario will over-ride the results of the previous run for that scenario.

1. Select the land use scenario for the simulation from the *Scenario* #drop down menu under the CLUES tools. At this stage, only the default or current land use (*Scenario #0*) is available (see Section 6 for scenario creation).

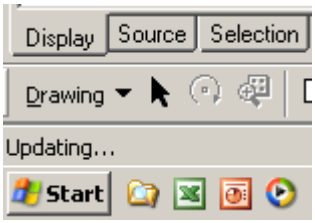


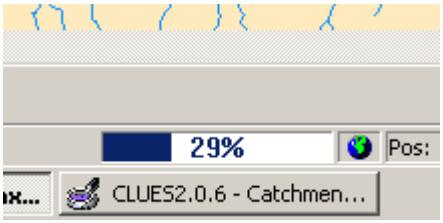
2. Click the *RUN* button under CLUES tools. The simulation time will vary depending on the area to be modelled.

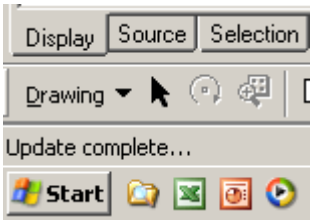
TROUBLE SHOOTING: I get this message when I try to run CLUES:

This means that there are no river reaches selected for simulation. Select river reaches and re-run CLUES.

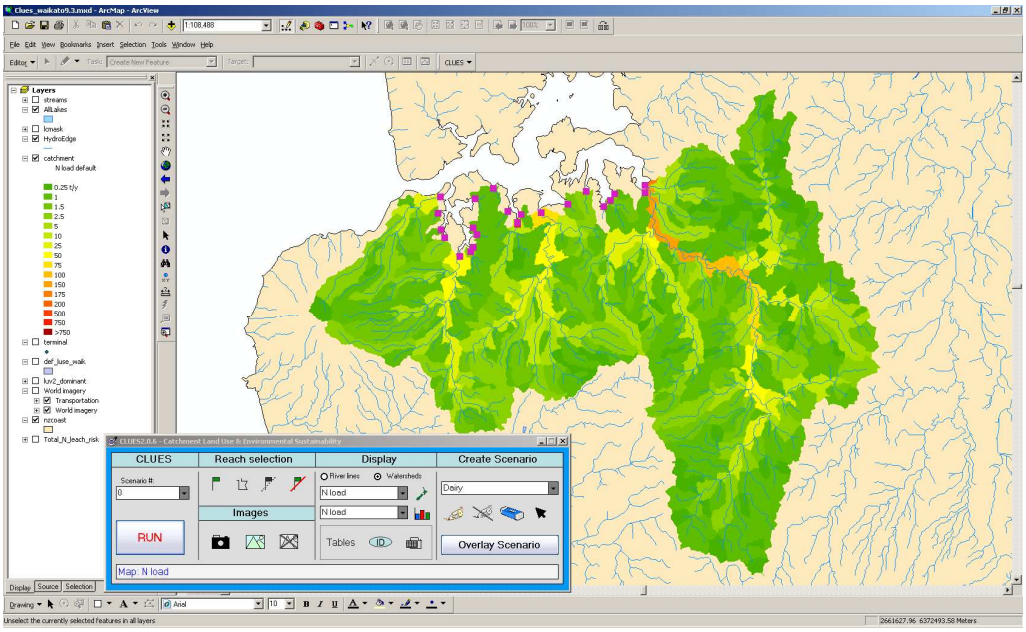
The status bar at the bottom of the ArcGIS screen will give information about the estimated run time and simulation progress







3. The default display is a watershed map of cumulative N loads for the selected river reaches (i.e., displayed as sub-catchments). The *catchment* layer will automatically be activated in the *TOC* with the legend expanded for display.

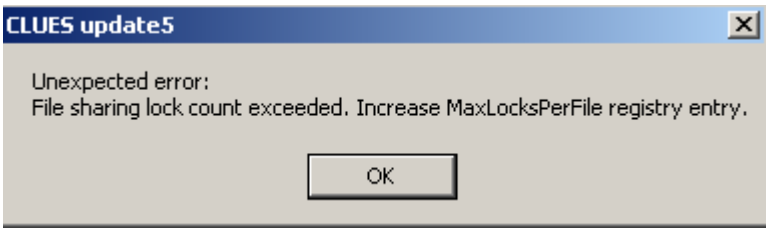


In this example, the selection highlighting has been switched off using the ArcGIS selection tools, however the CLUES reach selection (as indicated by the cerise terminal reach tags) remains and can be used for later runs.

The CLUES selection can be removed for display by deselecting within CLUES 2.0.6, however, the reaches will need to be reselected for later runs. If you plan to run the same selection of reaches for a number of land use scenarios, it is recommended that you do not deselect the reaches until all the runs are complete to ensure that the same reaches are simulated. The reaches can then be deselected safely and the results displayed.

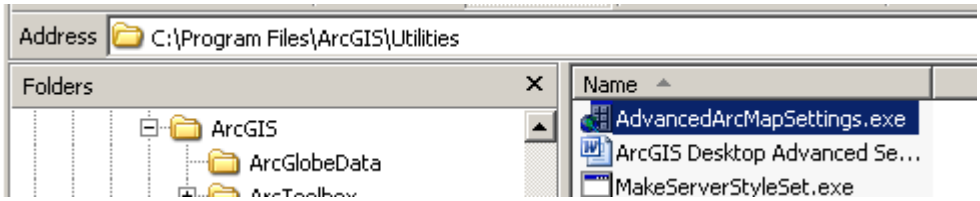
CLUES catchment selections are not saved when ArcGIS is closed.

TROUBLE SHOOTING: When I run CLUES, I get this error.

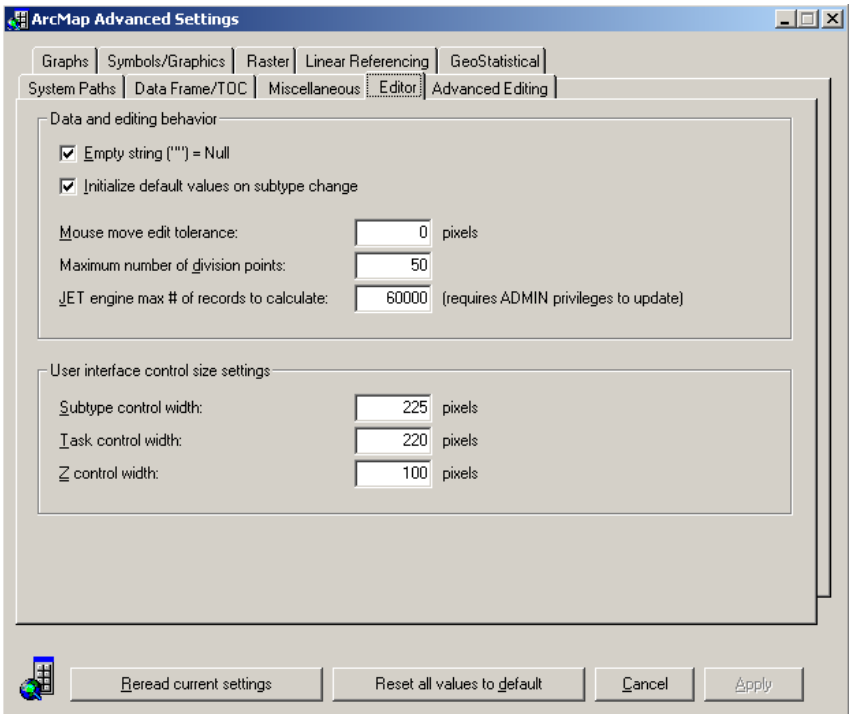


This means that the ArcMap default settings are not compatible with CLUES 2.0.6 requirements and will need to be reset. You will need administrative privileges to carry out the following instructions.

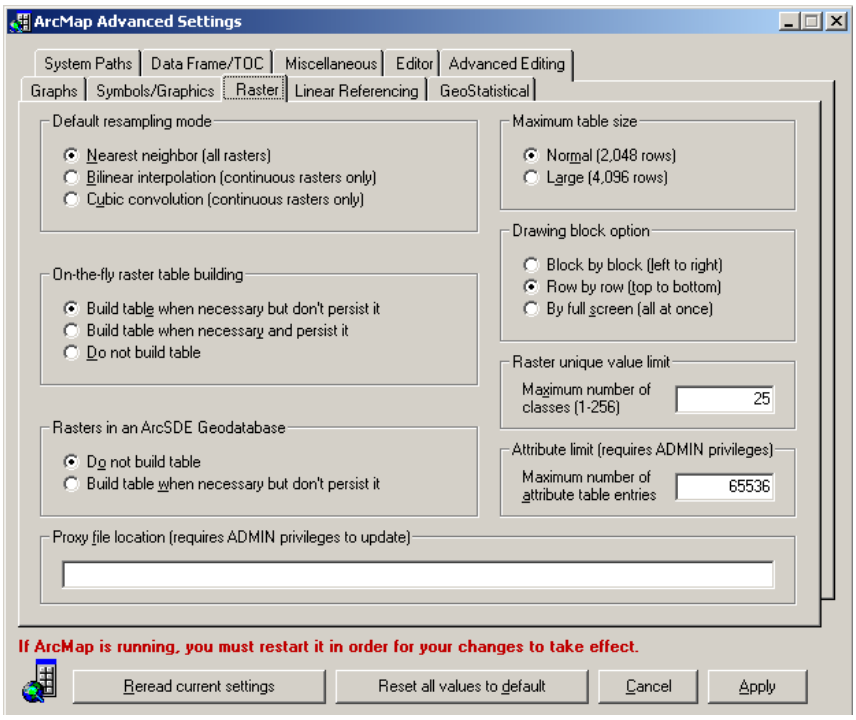
1. Close ArcMap. In Explorer, navigate to the ArcGIS Utilities directory and open AdvancedArcMapSettings.exe.



2. Select the *Editor* tab and set *JET engine max #of records* option to 60000.



3. Click the *Raster* tab and set the *Maximum number of attribute table entries* option to 65536. Click the *Apply* button and close the dialogue box.



4. Open ArcMap and re-run CLUES 2.0.6

5. Displaying Model Results

CLUES results for the simulated river reaches are held in the *catchment* layer and can be viewed directly by opening the *catchment* attribute table (see Appendix Two for list of result fields in the *catchment* layer). This layer is joined to the *streams* layer for display of river line maps. River reaches which are not simulated are assigned default values of -0.1 for all the result fields. CLUES has automatic display options / symbology for maps, bar charts and tables (see Section 7 for instruction on how to change symbology). Bar charts and tables are primarily intended as tools to compare the results of different land use scenario simulations (see Section 6.4). In addition to CLUES results, CLUES 2.0.6 has ESRI World Imagery layers as a reference for display. For this example, model results for the streams flowing into the southern part of Raglan Harbour will be displayed.

5.1 Maps

There are three types of map available in CLUES 2.0.6:

- River lines – available for nutrient, sediment and E. coli loads, nutrient concentrations, and nutrient and sediment cumulative yields
- Watersheds – available for nutrient, sediment and E. coli loads, nutrient concentrations, and nutrient and sediment generative yields
- Total nitrogen loss risk dockable map – the nitrogen loss risk layer (raster) from EnSus

The map legend for each map type is found under in the *TOC* which is automatically updated and expanded depending on the type of map displayed. CLUES maps have a default symbology which can be changed (see Section 7.1)—selecting a new map will reset the symbology to the default.

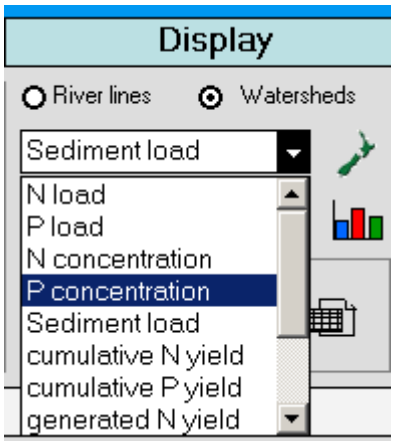
In addition to the CLUES maps, CLUES 2.0.6 has a link to ESRI World Imagery for display.

5.1.1 Watersheds

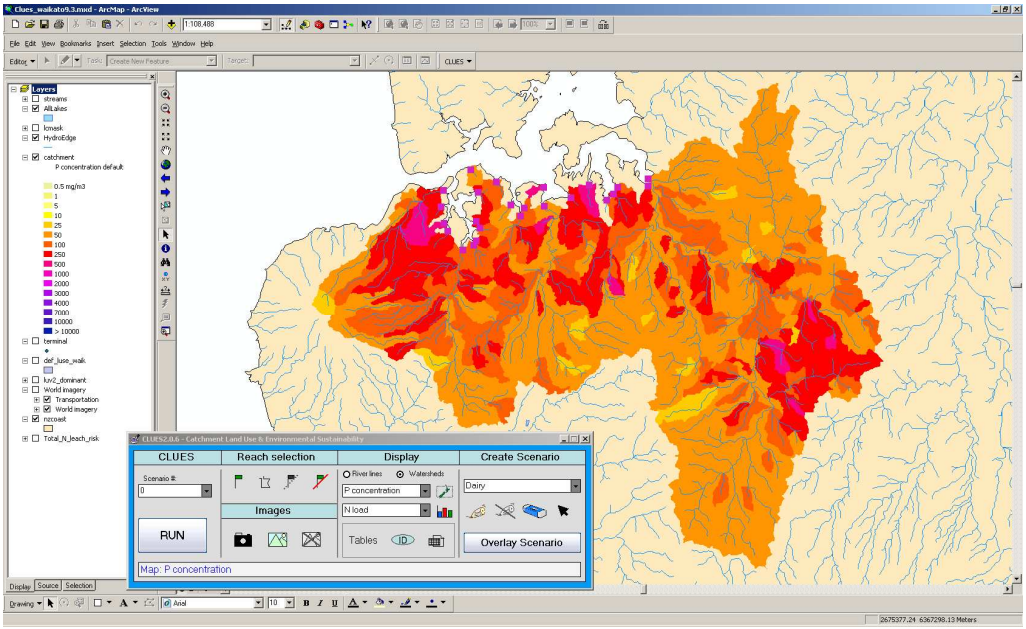
Watershed maps shade the sub-catchments for the selected river reaches with a graduated colour ramp. The map legend is found under the *catchment* layer in the *TOC*. The default map display after running CLUES is a watershed map of N load.

1. Check the *Watersheds* radio button under the CLUES *Display* tools.

2. Chose the result to be mapped from the *Map* drop-down menu under *Display* tools and click the *Map* icon.



The map selected will be drawn on the display screen and the variable mapped will appear in the *CLUES Display* bar. This example is the median P concentration. The map has a default symbology with the legend automatically lists in the *TOC* under the *catchment* layer.



TROUBLE SHOOTING: When I tried to select a map for display, the CLUES interface went into a loop with the two display drop-down menus flickering and my PC froze so I could not close CLUES.

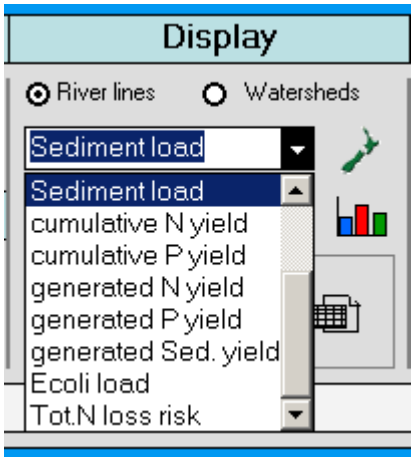
We are not sure what causes this bug, which occurs very occasionally. You will need to force ArcGIS to quit using Task Manager (*Alt+Ctrl+delete*) or, failing that, manually switching off your computer. Restart ArcGIS and CLUES as normal.

5.1.2 River lines

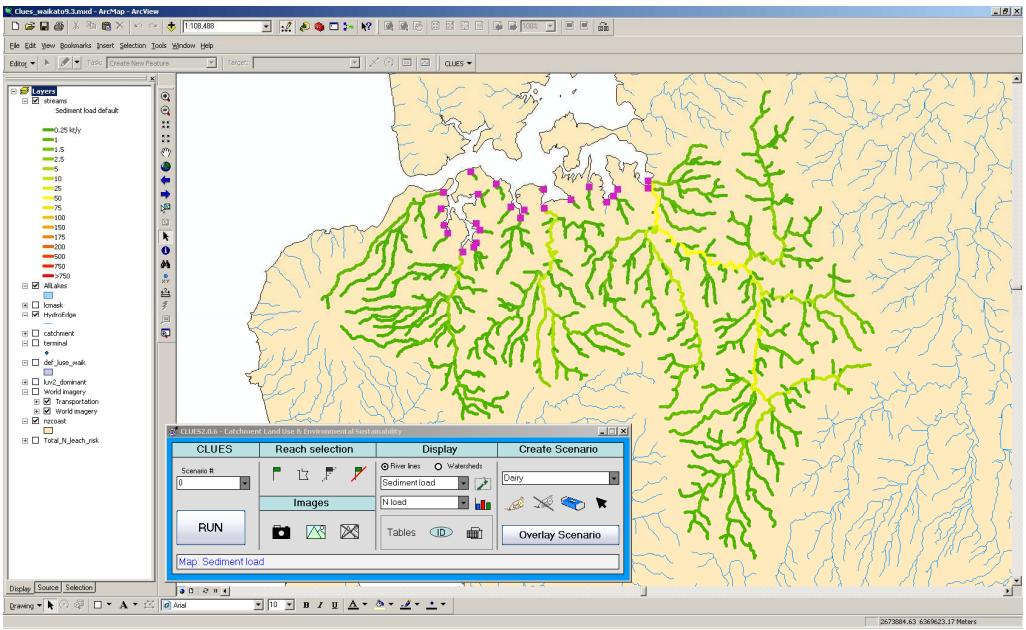
River line maps highlight the selected stream network with a variable colour scale.

1. Check the *River lines* radio button under the *Display* tools.

2. Chose the result to be mapped from the *Map* drop-down menu under *Display* tools and click the *Map* icon.



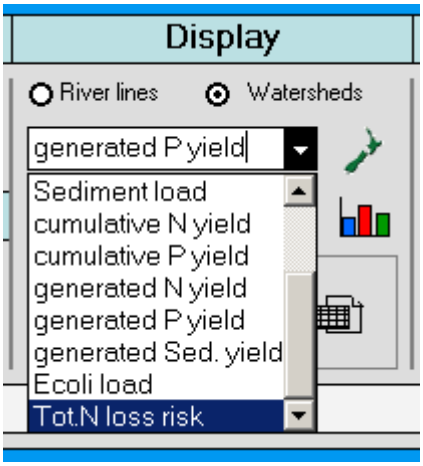
The map selected will be drawn on the display screen with the CLUES default symbology. The stream network will be displayed according to the variable chosen and the legend listed in the *TOC* under the *streams* layer. The variable mapped will appear in the CLUES Display bar. This example is the sediment load.



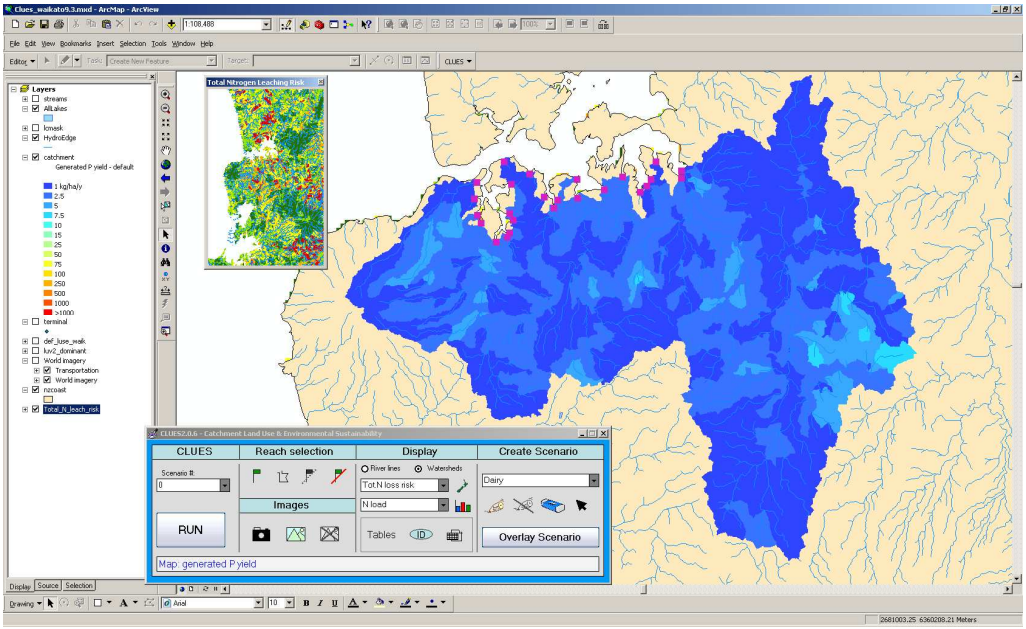
5.1.3 Total nitrogen loss risk

The total nitrogen loss risk map is a dockable window that can be moved around the screen and placed with the *TOC* as a side window. The map displays the *Total_N_leach_risk* layer. This layer covers the entire country and is not confined to the simulated river reaches. The layer is rasterised with a spatial resolution of 100 m (1 ha) and will follow any zooming or panning in the main display map. If there are two monitors available, the map can be placed on the second screen. NOTE that activating the dockable window automatically selects the *Total_N_leach_risk* layer in the *TOC* for display in the main display, but the layer is masked by *nzcoast*.

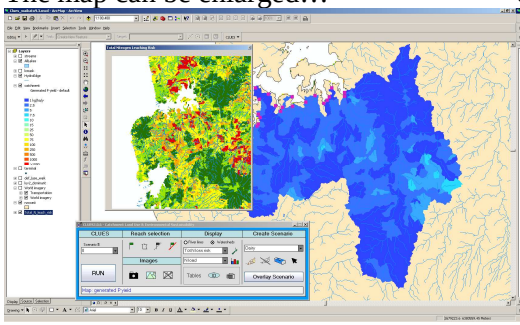
1. Select *Total N loss risk* from the *Map* drop-down menu under CLUES *Display* tools and click the *Map* icon.



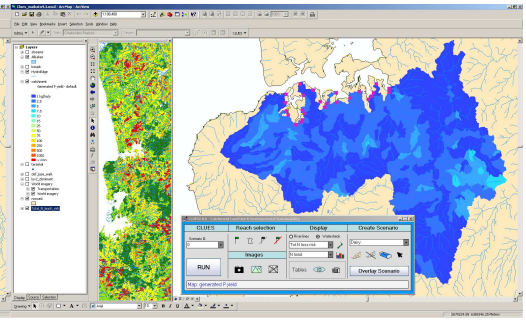
The total nitrogen loss risk map will appear as a dockable window. Here the main display shows the generated P yield.



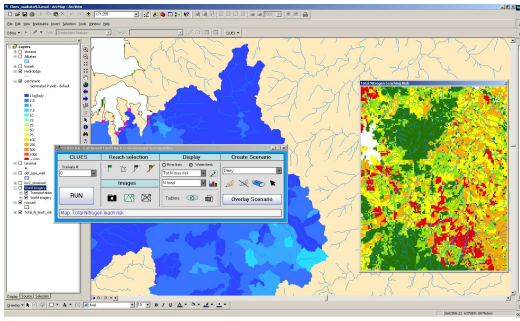
The map can be enlarged…



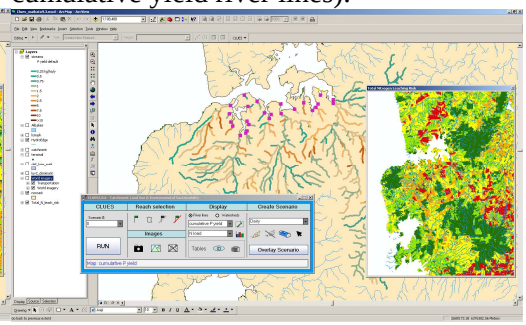
or "docked" to the side.



Panning and zooming will be traced.

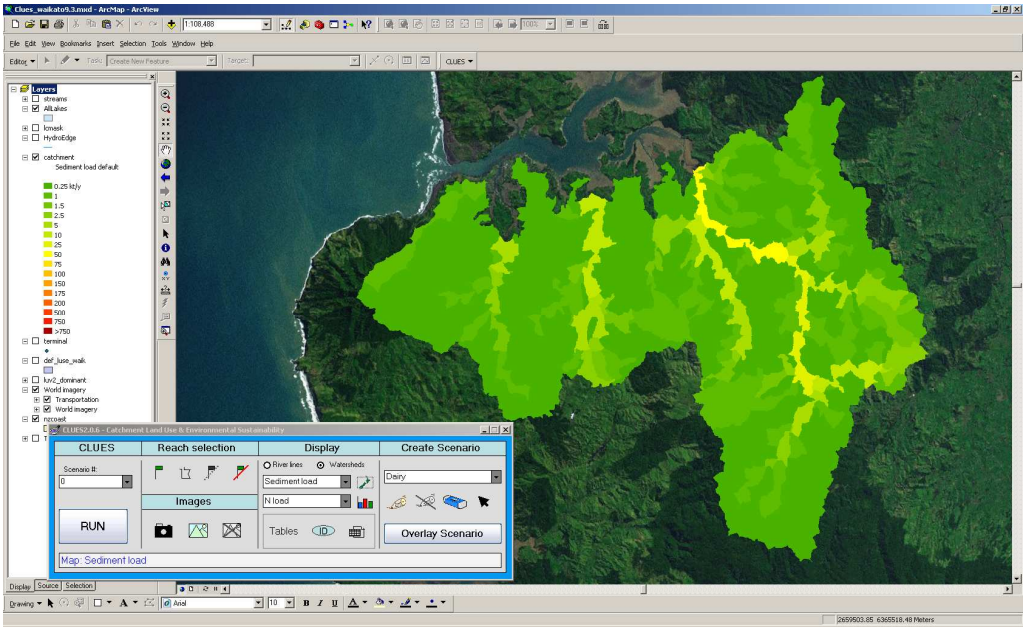


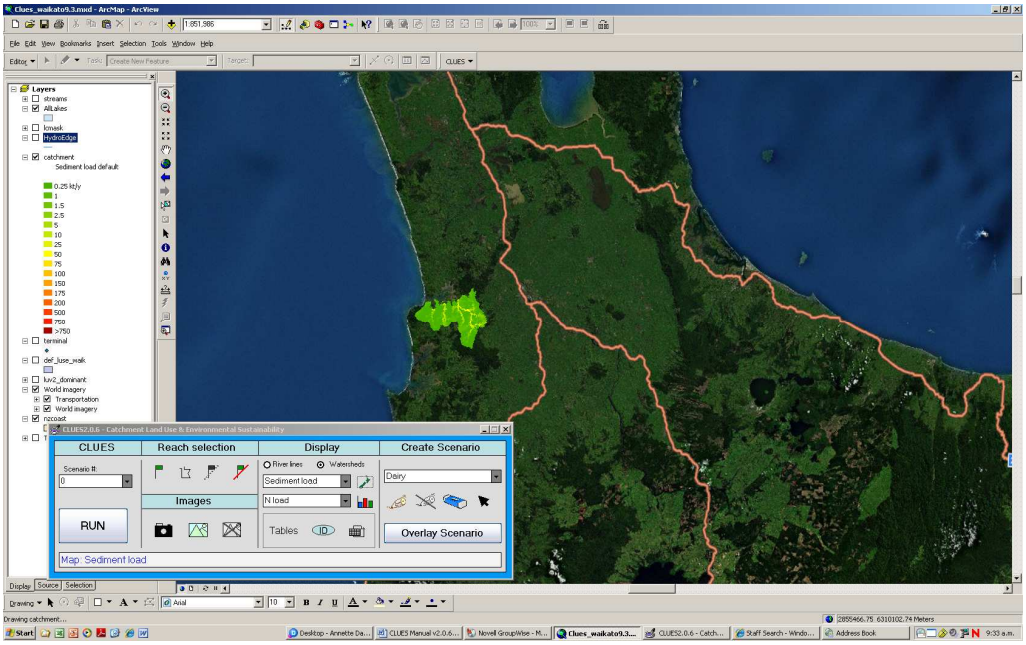
The map can be left active while working with other display options (here P cumulative yield river lines).



5.1.4 ESRI World Imagery

New to CLUES 2.0.6 is a link to ESRI on-line world imagery layers including aerial / satellite images and major transport routes / airports. Your PC must have an active network connection to display these layers. The layers have been provided for display only to aid in land use scenario creation and result interpretation. They are not used by CLUES for model simulation. Like the *Total_N_leach_risk* layer, these layers cover the entire country and are not restricted to region. To display the layers, check *World Imagery* in the *TOC*. This example shows sediment loads with the ESRI layers.

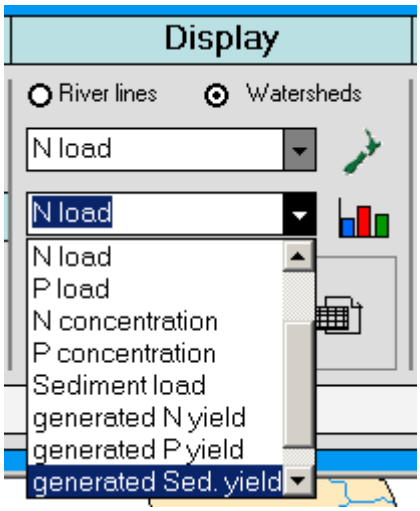




5.2 Bar charts

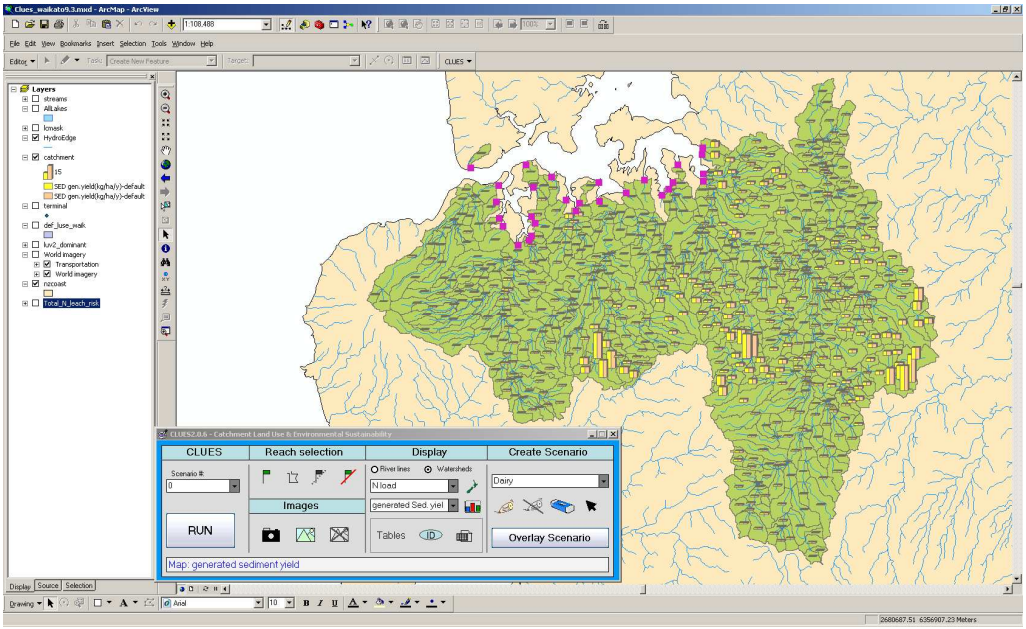
Bar charts are available for nutrient sediment and *E. coli* loads, nutrient concentrations, generated nutrient and sediment yields, nitrogen loss (leaching) and the economic indicators GDP, FTE and CFS. In each case, bars for each sub-catchment will be drawn on the map layer. The bar chart legend is provided under the *catchment* layer in the *TOC*. The primary function of bar charts is to provide a geo-visualisation tool which shows the impacts of land use change compared to the default land use (see Section 6.4.2). For this reason, bar charts have two bars for each sub-catchment. In the example below, no new land use scenarios have been created, hence, the two bars will be the same and relate only to the default land use (*Scenario* #0).

1. Select the variable to be displayed from the *Chart* drop-down menu under CLUES *Display* tools. Here the generated sediment yield is plotted.



2. Click the *Chart* icon under *Display* tools.

The bar chart legend will appear in the *TOC* under the *catchment* layer and the result mapped will appear on the CLUES *Display* bar. There are two bars per sub-catchment, at this stage, only the default land use has been simulated and the bars are the same height for each sub-catchment.



5.3 Tables

CLUES 2.0.6 has two types of table to display model results:

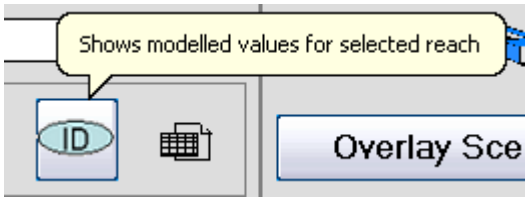
- Sub-catchment summary—identifies results for a selected river reach sub-catchments; and
- Modelled area summary—summarises the results for each of the sub-catchments in the modelled area.

Tables are a useful tool for comparing the impacts of land use change compared to the default land use (see Section 6.4.3). In the examples below, no new land use scenarios have been created, hence, the tables will only display the results for the default land use (*Scenario* #0).

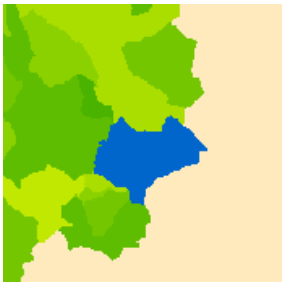
5.3.1 Sub-catchment summary

The sub-catchment summary table gives results for nutrient loads, concentrations and yields, sediment load and yield, *E. coli* load and economic indicators.

1. Click the *Identify sub-catchment* icon under CLUES *Display* tools. The cursor will change to a black arrow and question mark .



2. Click on the sub-catchment to be investigated. The sub-catchment polygon will flash once to show its boundaries and the catchment summary table will open displaying results for that sub-catchment. Clicking on other sub-catchments will update the table.



N /P Loads, Triple Bottom Output

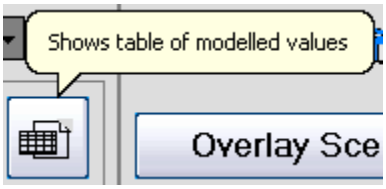
AREA_HA	170.730
CFS($) - default	8309.710
FTE - default	0.091
GDP($) - default	9049.100
N Conc(mg/m3) - default	638.025
N cum.yield(kg/ha/y)-default	14.516
N gen.yield(kg/ha/y)-default	16.392
N load(t/y) - default	2.478
P Conc(mg/m3) - default	193.820
P cum.yield(kg/ha/y)-default	4.779
P gen.yield(kg/ha/y)-default	5.040
P load(t/y) - default	0.816
peta E.coli per year-default	0.053
SED gen.yield(kg/ha/y)-default	12.420
SED load(kt/y) - default	2.121

If other land use scenarios have been modelled, the table will also summarise the results for the last model run for the selected scenario, see Section 6.4.3.

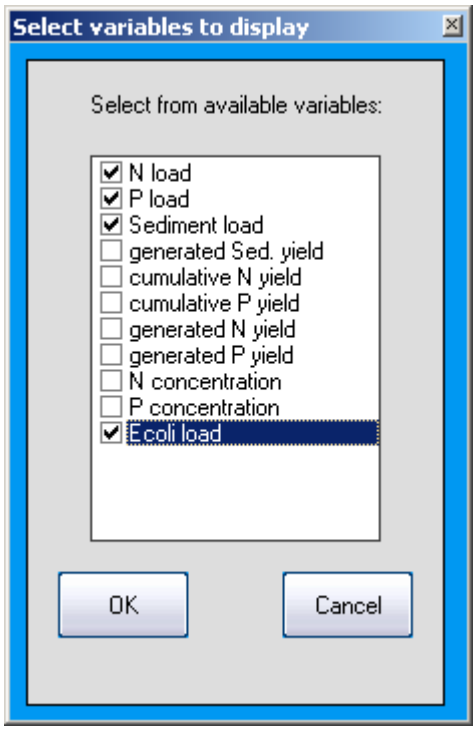
5.3.2 Modelled area summary

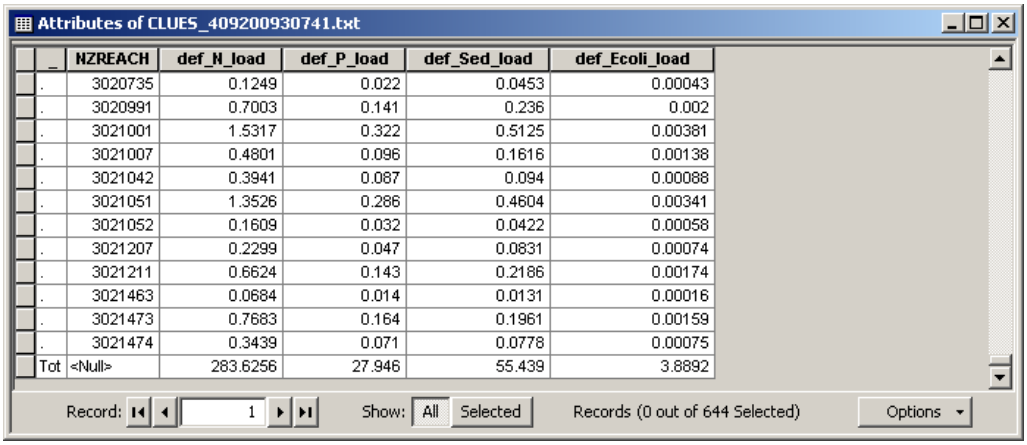
The modelled area summary table gives the simulated results for all the water quality parameters of the river reaches in the modelled area. The model results are listed for each sub-catchment. Sub-catchments can be identified by their river reach number (NZREACH) from the NIWA REC database. The summary table is saved as a text file (CSV or comma delineated), this means it can be opened directly in another package such as EXCEL for further analysis or plotting. The inclusion of the reach number as an identifier means the table can be joined to other layers for later analysis or display.

1. Click the *Modelled area summary* icon under CLUES *Display* tools.



2. Check the variables to be included in the summary table and click *OK* to display the table.

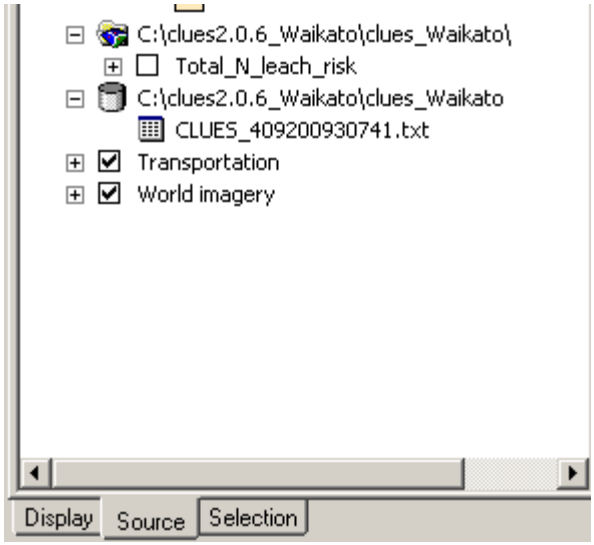




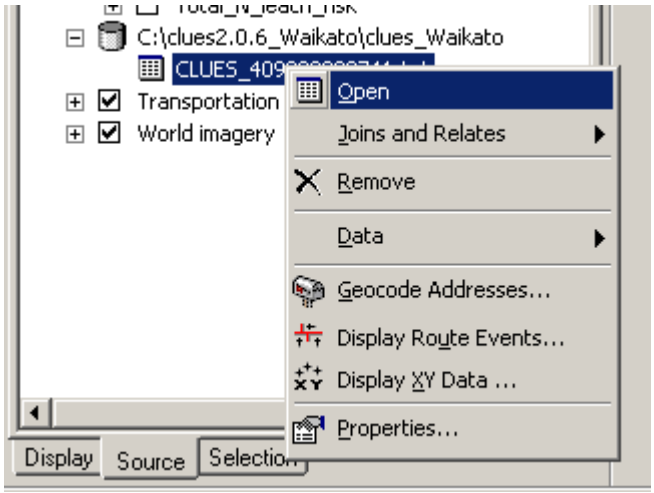
If new land use scenarios have been simulated, the table will also summarise the results for the last model run for the selected scenario, see Section 6.4.3.

Note that for loads and cumulative yields, the last row in the table is the cumulative total for the simulated river reaches. If only one catchment is simulated, the total will be equivalent the value at the selected / flagged river reach.

3. The table will be listed in the *TOC* under the *Source* tab which will automatically be selected. The table is stored in the CLUES 2.0.6 directory as a text file, the naming convention of the table and file is CLUES_#.txt where # is the date and time of the table creation; an "a" following the time denotes "am". In this example, the table was created on 4 September 2009 at 3:07:41 pm.

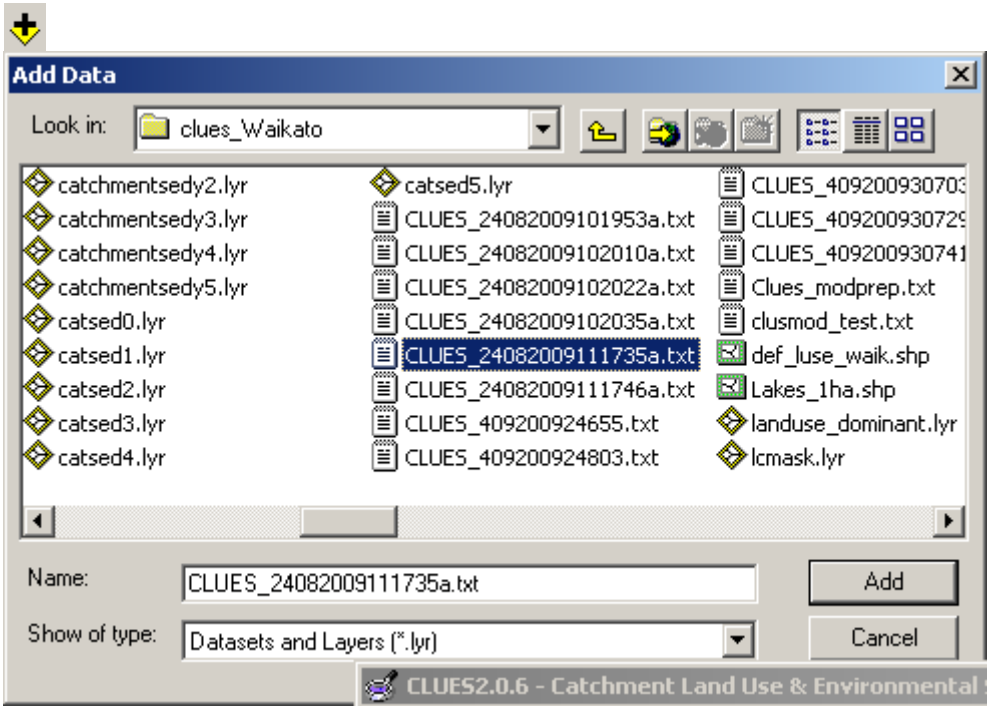


To re-open the table, right click on the text file listed under the *TOC* and click the Open command.

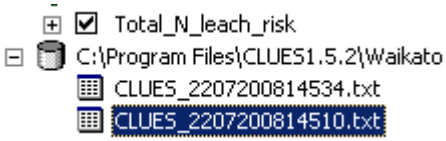


The table text file will be updated in the *TOC* each time a new summary table is created.

To list previous summary tables in the *TOC*, click the *Add data* icon on the ArcGIS Standard Toolbar and select the relevant text file. In this example, the table was created on 24 August 2009 at 11:17:35 am

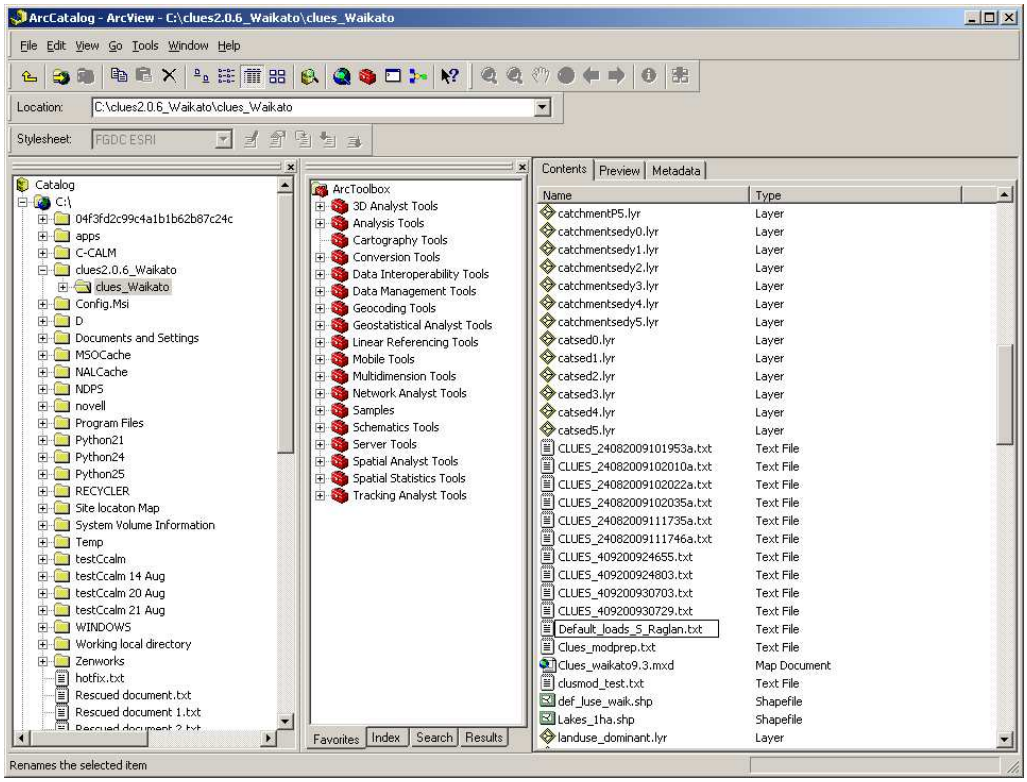


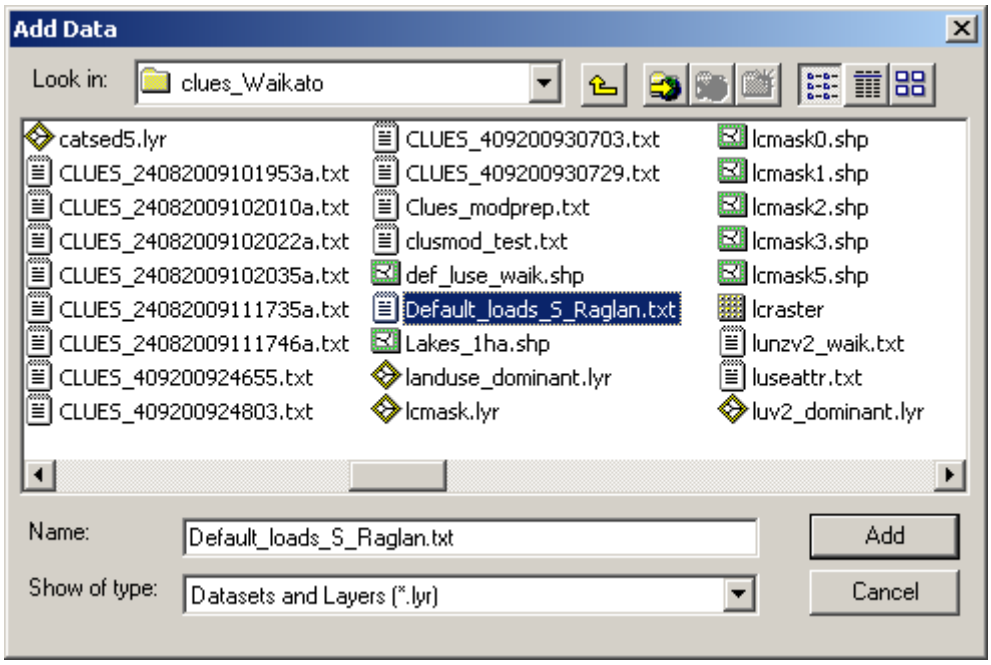
Click *OK*. The table should now appear in the *TOC*.

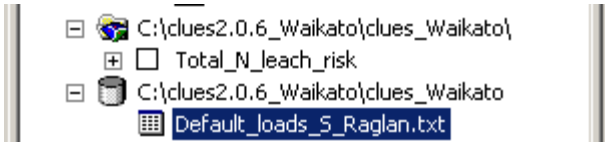


TIP: If you plan to refer to tables at a later date, it is a good idea to either make a reference list describing the contents of each table (e.g., scenario and catchment selection) or to remove the table from the *TOC* (right click and select *Remove*) and re-name it using either ArcCatalog or Windows Explorer. The renamed table can then be added to the *TOC* as above for future reference.

Renaming in the ArcGIS *TOC* will change the name for display, but not the name of the source file.


ArcCatalog - ArcView - C:\clues2.0.6_Waikato\clues_Waikato
File Edit View Go Tools Window Help
Location: C:\clues2.0.6_Waikato\clues_Waikato
Stylesheet: FGDC ESRI
Catalog
C:\
04f3fd2c99c4a1b1b62b87c24c
apps
C-CALM
clues2.0.6_Waikato
clues_Waikato
Config.Msi
D
Documents and Settings
MSOCache
NALCache
NDPS
novell
Program Files
Python21
Python24
Python25
RECYCLER
Site locaton Map
System Volume Information
Temp
testCcalm
testCcalm 14 Aug
testCcalm 20 Aug
testCcalm 21 Aug
WINDOWS
Working local directory
Zenworks
hotfix.txt
Rescued document.txt
Rescued document 1.txt
ArcToolbox
3D Analyst Tools
Analysis Tools
Cartography Tools
Conversion Tools
Data Interoperability Tools
Data Management Tools
Geocoding Tools
Geostatistical Analyst Tools
Linear Referencing Tools
Mobile Tools
Multidimension Tools
Network Analyst Tools
Samples
Schematics Tools
Server Tools
Spatial Analyst Tools
Spatial Statistics Tools
Tracking Analyst Tools
Favorites Index Search Results
Contents Preview Metadata
Name Type
catchmentP5.lyr Layer
catchmentsedy0.lyr Layer
catchmentsedy1.lyr Layer
catchmentsedy2.lyr Layer
catchmentsedy3.lyr Layer
catchmentsedy4.lyr Layer
catchmentsedy5.lyr Layer
catsed0.lyr Layer
catsed1.lyr Layer
catsed2.lyr Layer
catsed3.lyr Layer
catsed4.lyr Layer
catsed5.lyr Layer
CLUES_24082009101953a.txt Text File
CLUES_24082009102010a.txt Text File
CLUES_24082009102022a.txt Text File
CLUES_24082009102035a.txt Text File
CLUES_24082009111735a.txt Text File
CLUES_24082009111746a.txt Text File
CLUES_409200924655.txt Text File
CLUES_409200924803.txt Text File
CLUES_409200930703.txt Text File
CLUES_409200930729.txt Text File
Default_loads_S_Raglan.txt Text File
Clues_modprep.txt Text File
Clues_waikato9.3.mxd Map Document
clusmod_test.txt Text File
def_luse_waik.shp Shapefile
Lakes_1ha.shp Shapefile
landuse_dominant.lyr Layer
Renames the selected item


Add Data
Look in: clues_Waikato
catsed5.lyr
CLUES_24082009101953a.txt
CLUES_24082009102010a.txt
CLUES_24082009102022a.txt
CLUES_24082009102035a.txt
CLUES_24082009111735a.txt
CLUES_24082009111746a.txt
CLUES_409200924655.txt
CLUES_409200924803.txt
CLUES_409200930703.txt
CLUES_409200930729.txt
Clues_modprep.txt
clusmod_test.txt
def_luse_waik.shp
Default_loads_S_Raglan.txt
Lakes_1ha.shp
landuse_dominant.lyr
lcmask.lyr
lcmask0.shp
lcmask1.shp
lcmask2.shp
lcmask3.shp
lcmask5.shp
lcraster
lunzv2_waik.txt
luseattr.txt
luv2_dominant.lyr
Name: Default_loads_S_Raglan.txt
Add
Show of type: Datasets and Layers (*.lyr)
Cancel


C:\clues2.0.6_Waikato\clues_Waikato\
Total_N_leach_risk
C:\clues2.0.6_Waikato\clues_Waikato
Default_loads_S_Raglan.txt

6. Analysis: Working with Scenarios

One of the features of CLUES 2.0.6 is the ability to create land use scenarios to evaluate the impact of changed land use on long term water quality and economic indicators. Up to five other land use scenarios can be created and stored in CLUES at any one time to simulate and compare the effects of land use change. These effects can be compared using visual tools and tables. Saving the map document will also save the scenario.

There are three ways to create new land use scenarios, by:

- using the interactive sketch overlay tools to draw land use polygons over the default scenario;
- copying and altering the mock-up land use layer provided with CLUES 2.0.6 (*def_luse_region*); and
- importing land use layers.

The first method uses an in-built CLUES masking tool, the latter two use standard GIS functions for creating, editing and importing new shape files. While CLUES simulates river reaches and their associated sub-catchments as polygons, land use information is rasterised (default land use has a grid with 30 m pixels). Once a changed land use polygon layer has been created, the CLUES Overlay Scenario function rasterises the land use to create a new land use scenario. Depending on the on the chosen overlay creation mode, land use change scenarios have pixels of 30 m / 0.09 ha (accurate mode) or 100 m / 1 ha (fast mode).

NOTE: It is important when analysing land use change that CLUES 2.0.6 is run for the selected river reaches both with the default scenario and the new scenario(s) in order to ensure continuity between simulations. Do not deselect the tagged river network until all the required scenarios have been simulated.

6.1 Interactive Sketch Overlays

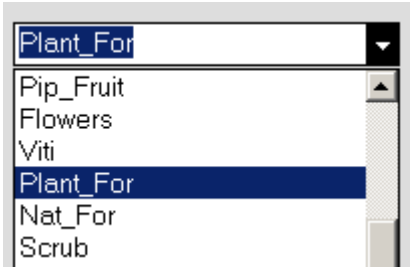
The Interactive Sketch Overlay tools allow new land use scenarios to be created quickly and easily by masking the default land use (not available for display or editing to users) with user drawn land use polygons.

In the following example, the land use south of Raglan Harbour which is currently predominantly pasture (dairy, sheep and beef) will be split between exotic or plantation forest and flowers.

1. Check and expand the interactive sketch masking layer, *lcmask*, in the *TOC* Display tab to show the land uses available.

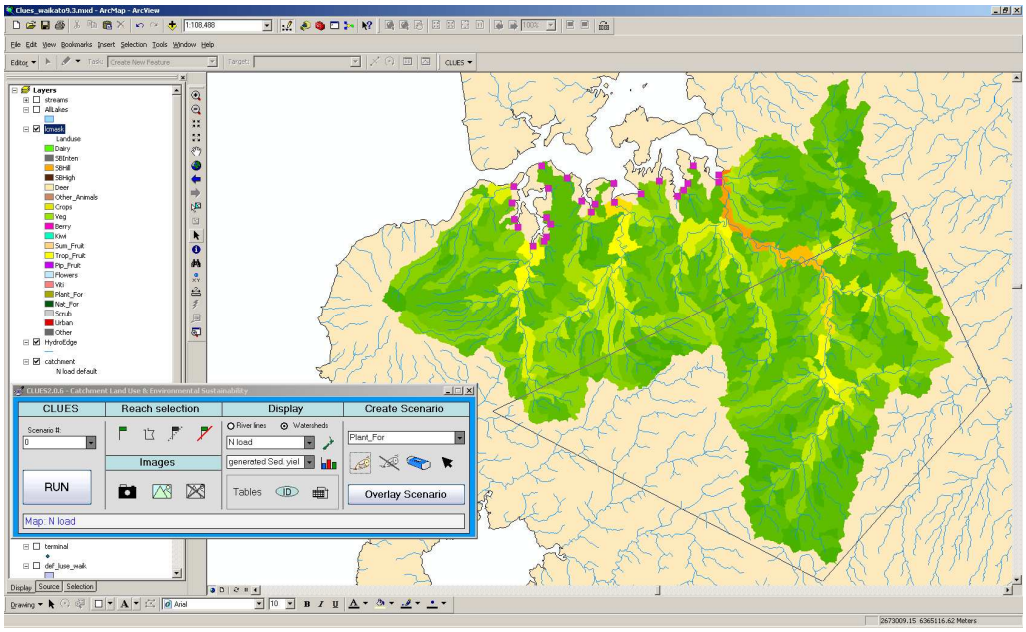
These land uses are the same as those defined for the attribute fields in Section 1.2.

2. Select the land use for the masking land use polygon from the *Land use* drop-down menu under CLUES *Create Scenario* tools (here Plant_For).

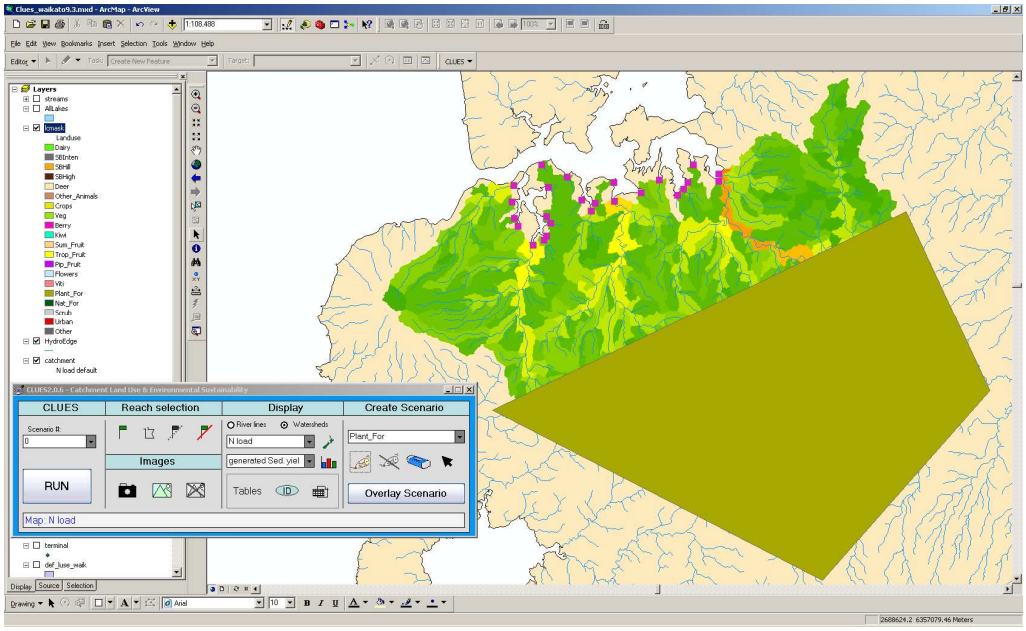


3. Click the *Draw land use polygon* icon to initiate create the land use polygon. The cursor will change to a hand and cross-hair.

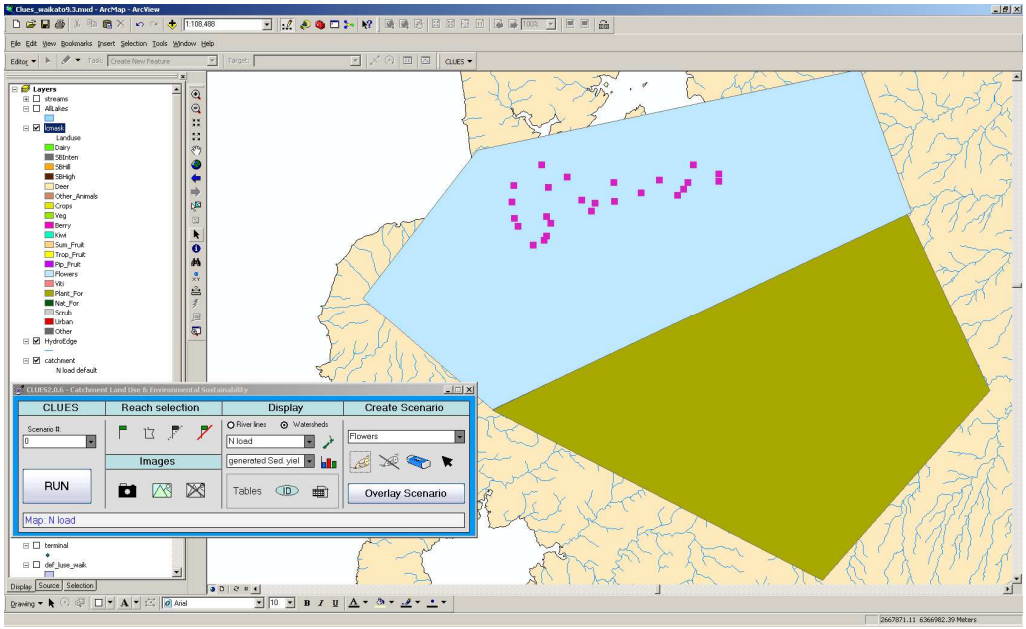
Position the cursor over the area to be modified. Click and drag to create a polygon—vertices are created at each click position.



Double click to complete the land use polygon.



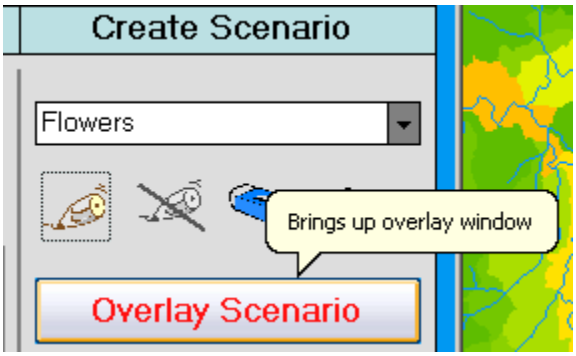
Select and draw polygons for the next land use type (here Flowers). NOTE that polygons are sequential with each polygon masking the one below.



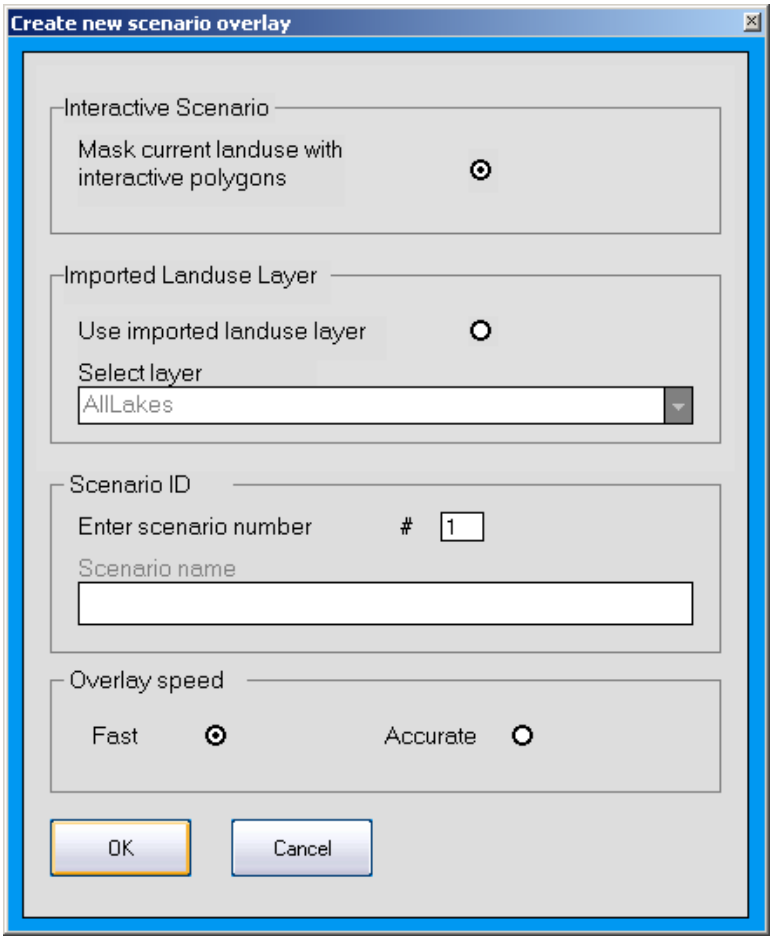
4. Clicking the *Eraser* icon will remove all the interactive land use polygons (i.e., the *lcmask* layer will be empty). A tool to remove polygons in sequential order is in development and is planned to be available in CLUES 3..

5. When the land use scenario is complete, click the *Cursor reset* icon to end the masking session and uncheck the *lcmask* layer in the *TOC*.

6. The interactive sketch land use scenario can now be laid over the default land use scenario to mask it within CLUES 2.0.6. Click the *Overlay Scenario* button under *Create Scenario* tools.



In the *Create new scenario overlay* dialogue box, select *Interactive Scenario* by clicking the *Mask current land use with interactive polygons* radio button. Under *Scenario ID* assign a scenario number from 1 to 5 (recall 0 is the default). Finally, select the *Overlay speed* by clicking the appropriate radio button and click *OK*.

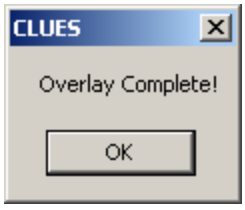


NOTE: there are two overlay speeds; *Fast* and *Accurate*. *Fast* mode creates a scenario with a pixel resolution of 100 m (1 ha) while *Accurate* mode creates a scenario with a pixel resolution of 30 m (0.09 ha). Choosing *Accurate* will result in a longer overlay time, typically several minutes. Given that the interactive sketch is by its nature a rough indication of land use change, *Accurate* is not recommended for the masked scenarios.

The overlay progress will be indicated in the ArcGIS status bar.

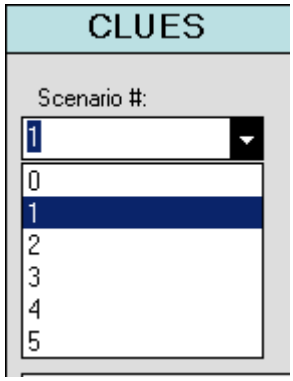
AVOID SWITCHING TO ANOTHER PROGRAM WHILE THE SCENARIO OVERLAY DIALOGUE BOX IS OPEN—THIS CAN CAUSE ArcGIS TO CRASH.

Click *OK* at the prompt.



NOTE, the larger the area covered, the longer time needed for masking.

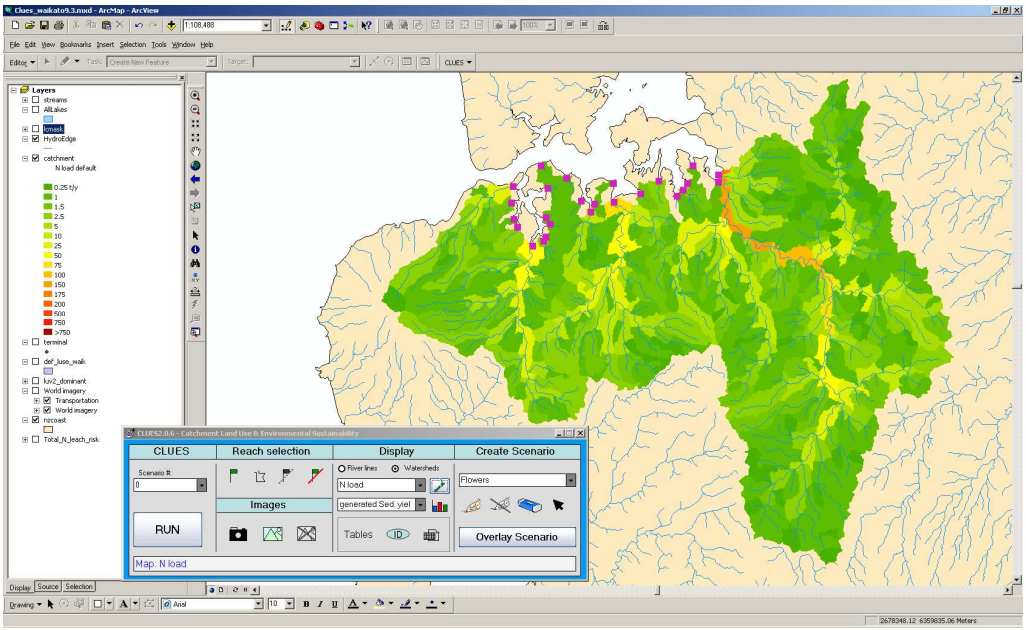
7. The CLUES modelling framework can now be run for the new scenario by selecting the relevant scenario number from the *Scenario* #drop-down menu and clicking the *RUN* button under the *CLUES* tools (see Section 6).



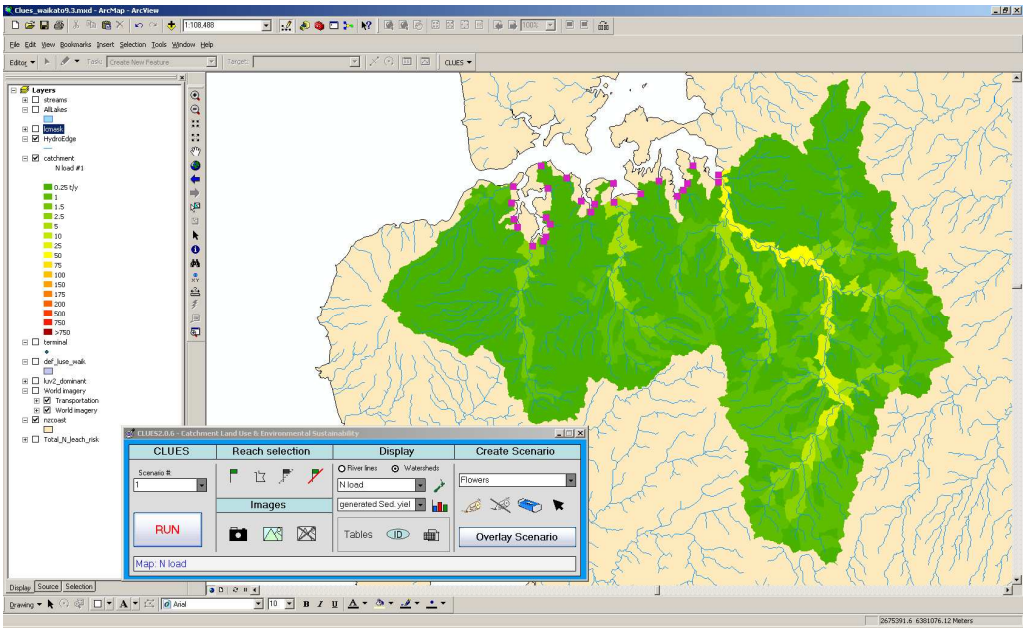
CLUES 2.0.6 will run for the selected river reaches using the new scenario. The default display is N load. NOTE: the legend in the *TOC* will be labelled with the appropriate scenario number (in the picture below, N LOAD #1). Options for comparing the results for different land use scenarios will be addressed in Section 6.4.

N load

Default land use: pastoral dairy, sheep and beef (*Scenario* #0)



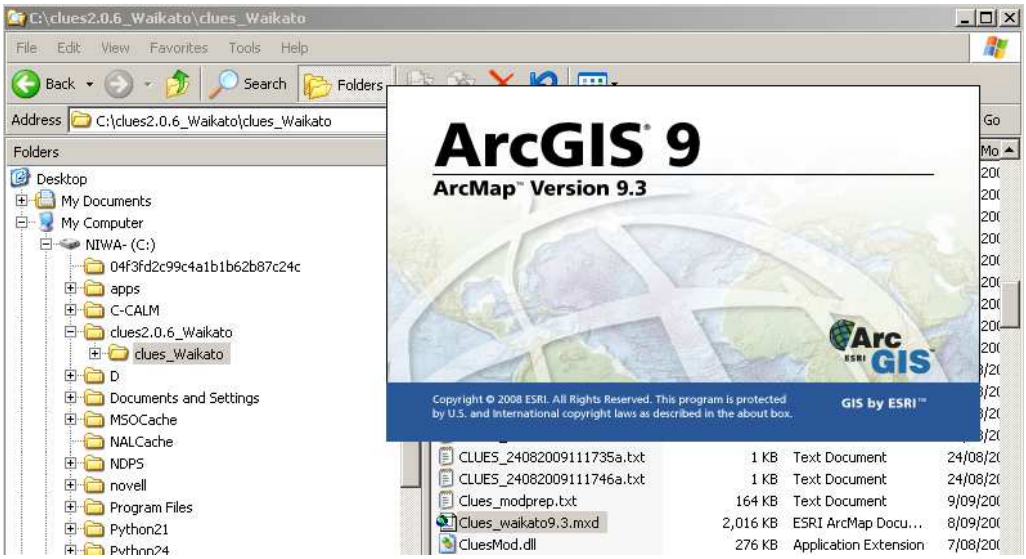
Flowers and plantation exotic forest (*Scenario* #1)



TROUBLE SHOOTING: Sometimes when I try to make a scenario in accurate mode I get this error.

This means that ArcGIS does not have enough memory required to carry out the overlay. Turn off any ArcGIS extensions (e.g., Spatial Analyst) you have running. Closing other software can also help.

You could also try closing ArcGIS and opening the map document directly from Window Explorer by double clicking the *.mxd* file provided in the regional CLUES folder.



6.2 Creating new scenarios using the default land use template

Land use scenarios can be created by copying and modifying an existing land use scenario using the ArcGIS attribute table *Field Calculator*. Users will need to have intermediate to advanced GIS skills. The steps are to export the layer as a new shape file and to then edit the attribute table either cell by cell; using the field calculation tool; or copying in data from another software package such as Excel. It is important to remember that the sum of the land use attributes for each polygon must be equal to 100%.

CLUES 2.0.6 has a built-in default current land use database (i.e., *Scenario* #0) which is not available to the user for either display or editing. However, a mock layer similar to the default has been supplied as a template to allow users to create land use change scenarios safely (*def_luse_waik* for Waikato) without affecting the CLUES 2.0.6 set-up[3]. This layer, and land use layers derived from it, should have the following fields:

FID	—	ArcGIS assigned ID
SHAPE	—	ArcGIS assigned shape field
GRID_CODE	—	Polygon identifier, each polygon is assigned a unique whole number
AREA	—	Reference field giving polygon area in square metres. This field is not used in scenario creation and can be deleted or omitted from land use layers.
Land use (22 fields)	—	Percentage of polygon covered by each of the CLUES land use categories (see Section 1.3 for code definitions). The row sum of these fields should equal 100%.

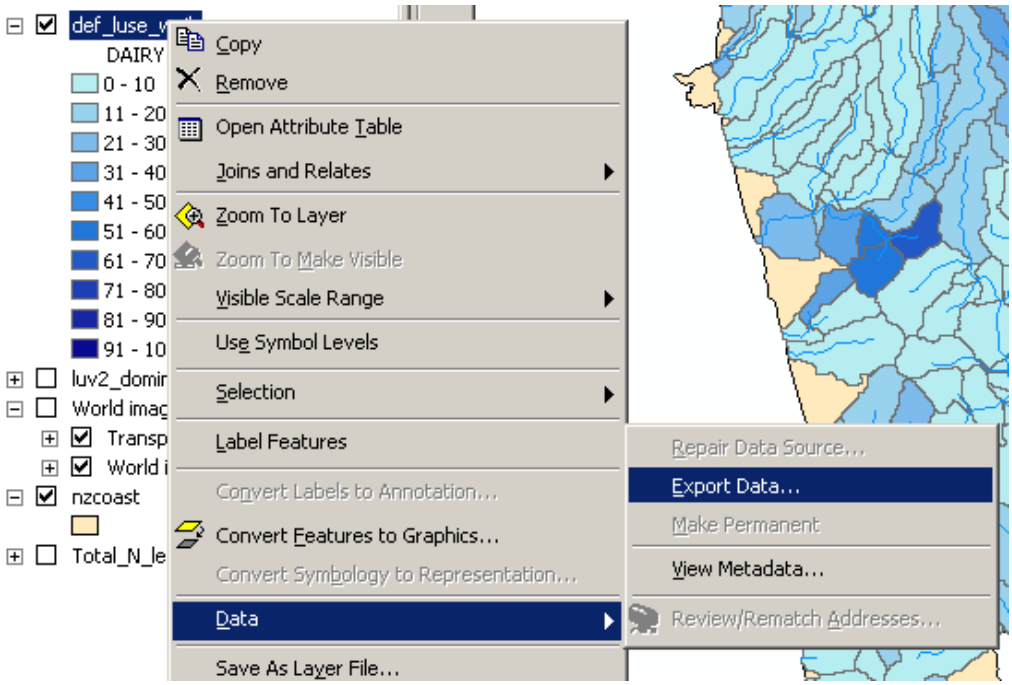
Land use layers used to create a scenario must have a GRID_CODE field and the land use fields; the AREA field can be omitted.

[3] NOTE: While the *def_luse_region* layer is very similar to the default land use scenario (Scenario #0), there are some minor differences due to different methods being employed in their derivation and storage in the CLUES database. If an exact comparison is needed, it is recommended that the *def_luse_region* layer be used to construct a land use scenario – this extra step has not been carried out for this manual.

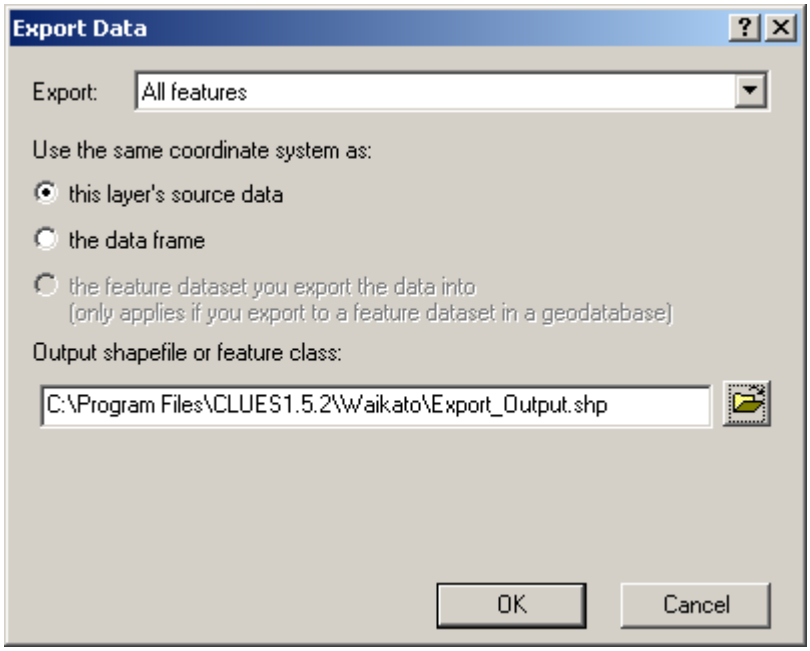
6.2.1 Example 1: Blanket changes to land use fields

Changing the relative percentage under each of the land use fields in the template layer (*def_luse_region*) is the easiest way to create a new land use layer for scenario creation. This can be done all values in a field using the ArcGIS *Field Calculator* or by pasting in copied column data from another package. In the example below, the proportion of sheep and beef farming for Waikato (i.e., land use types SBHILL, SBINTEN and SBHIGH) will be halved in favour of dairying (DAIRY), this will require several calculations. It is safest not to change the template so that it can use be re-used for further scenario creation. Instead, a new layer (*SB_to_dairy*) is created for this example. The symbology of the template layer has been altered to show the percentage of dairying by sub-catchment.

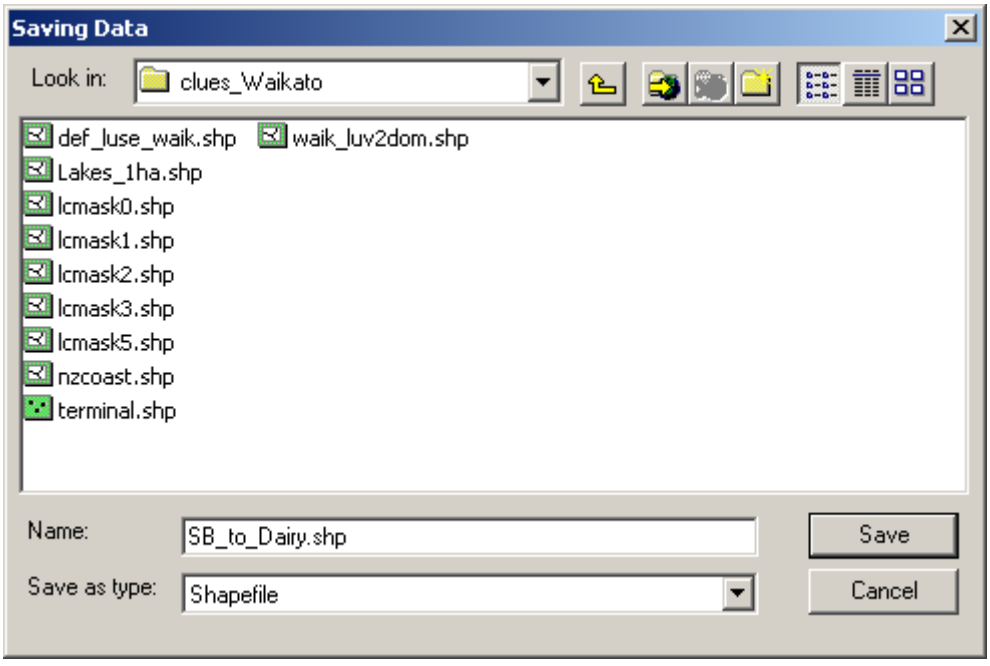
1. Right click on the default land use layer (for Waikato, *def_luse_waik*) in the *TOC*, select *Data* and click *Export Data*.



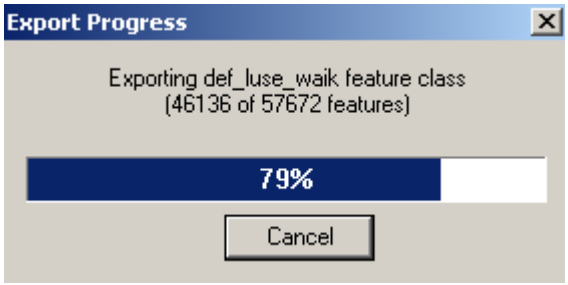
2. In the *Export Data* window, make sure *All features* is selected from the *Export* drop down menu. Note that the new shape file will be given a default name.



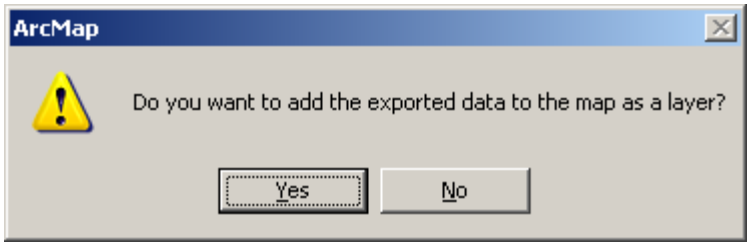
The new layer must be saved into the regional folder along with the map document. To change the directory pathway and name, click the *Folder* icon. This will open the *Saving Data* window. If necessary, navigate to the correct directory. Save the new shape file under a suitable name (*SB_to_dairy.shp* is used in this example). TIP: the file name cannot have spaces; use an underscore "_" instead.



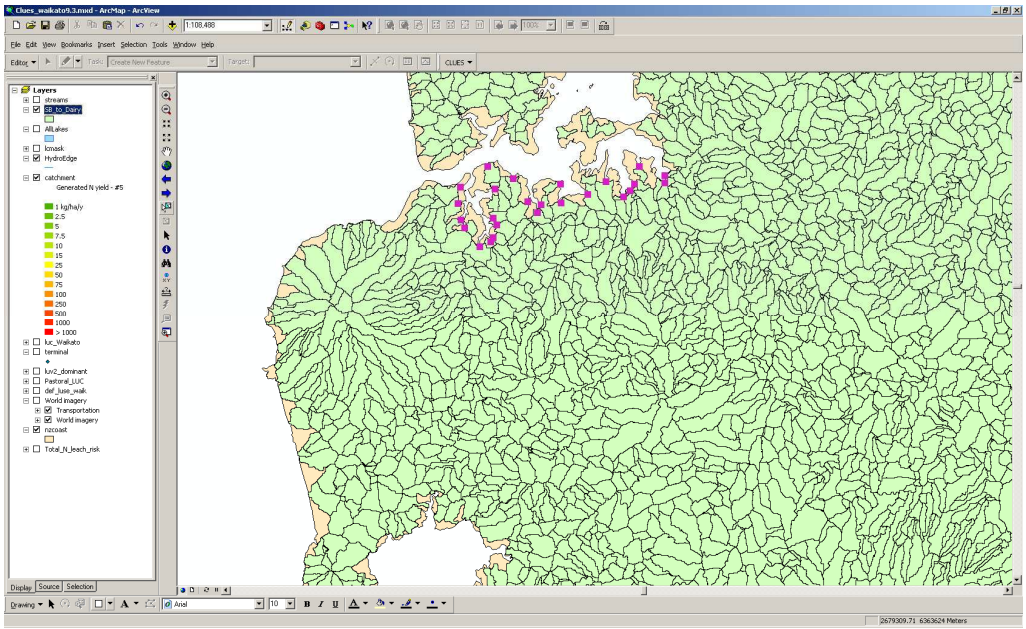
Click *OK* in the *Export Data* window. The export progress will be indicated by ArcGIS

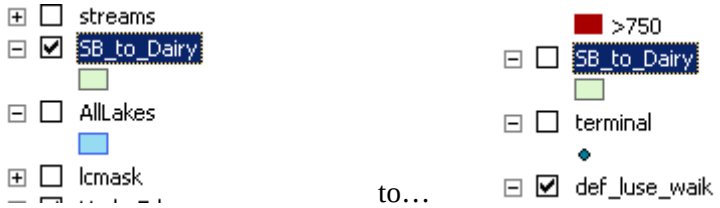


When the shape file has been exported, ArcGIS will ask if the layer is to be added to the map document. Click *Yes* at the prompt.



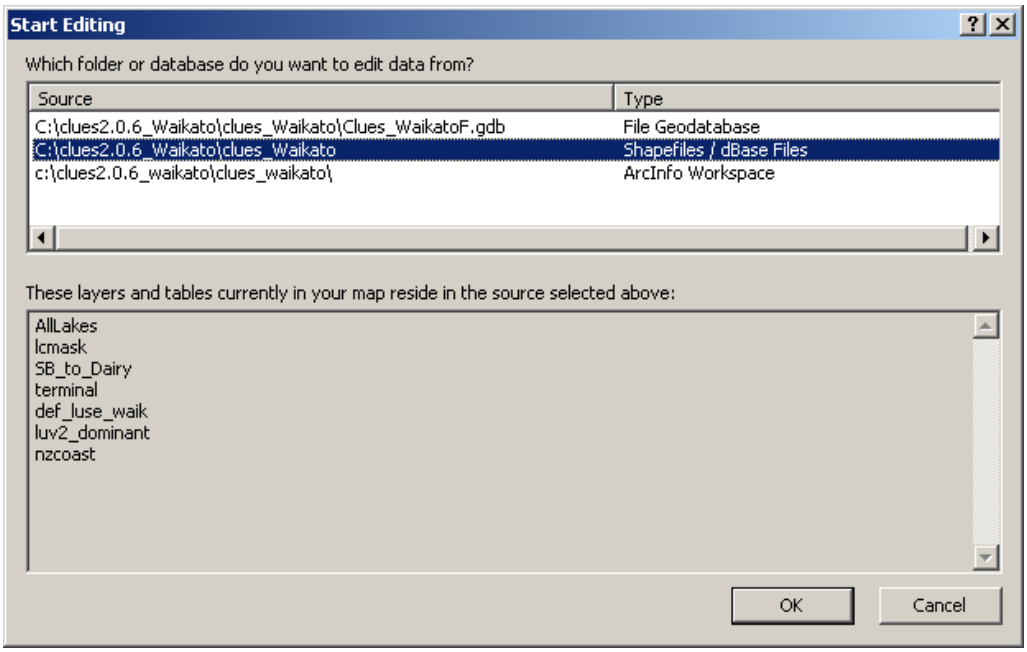
3. The default position of the new exported land use layer may cover the result display layers (*streams* and *catchment*). Uncheck the display box and move the layer in the *TOC* to a position below the *catchment* layer by clicking and dragging.



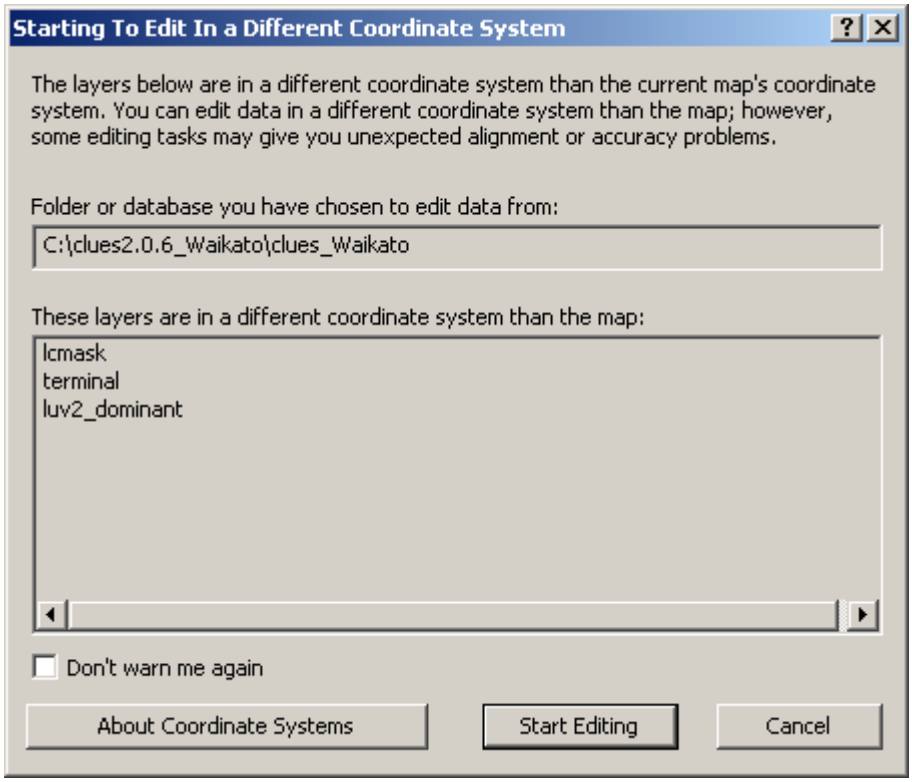


4. Although the *Field Calculator* can be used directly, it is recommended that the changes be carried out in editing mode for safety as modifications made outside editing mode cannot be reversed. To do this click *Start Editing* from the *Editor* toolbar.

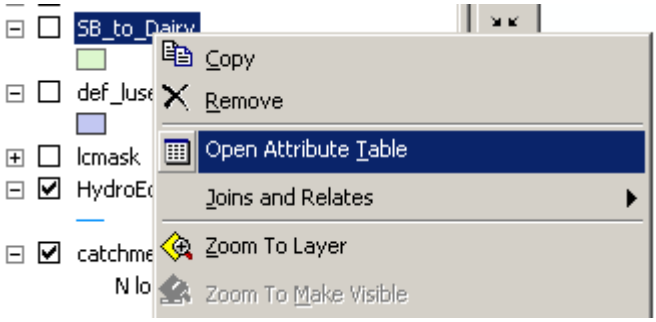
Select the relevant database folder (i.e., the folder containing the scenario shape file created above, in this case *SB_to_dairy*) from the *Start Editing* window. Click *OK*. This will activate the *Editor* toolbar.

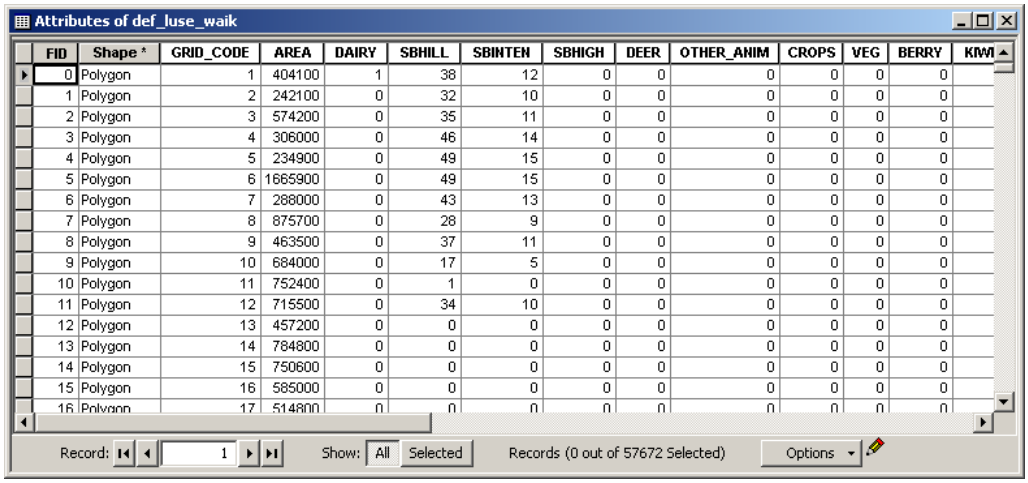


Note that you may get an error message about the layer co-ordinate system (i.e. layer projection), this will not affect CLUES 2.0.6 and can be safely ignored. Click *Start Editing* to activate the Editor toolbar.



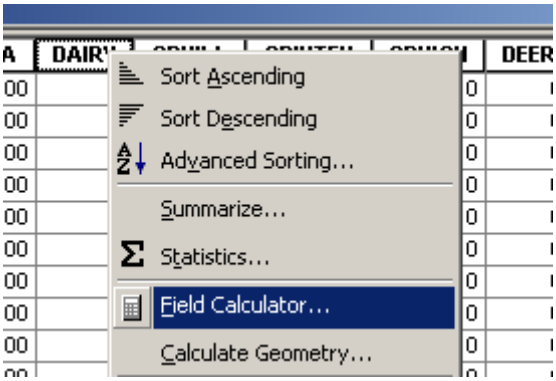
5. Open the attribute table for the new land use layer by right clicking on the layer in the *TOC*.





6. To paste in a column of data copied from another package such as Excel, click the top cell of the field to be adjusted and press *Ctrl+v*. The field will be updated. You will need to be in edit mode to paste data.

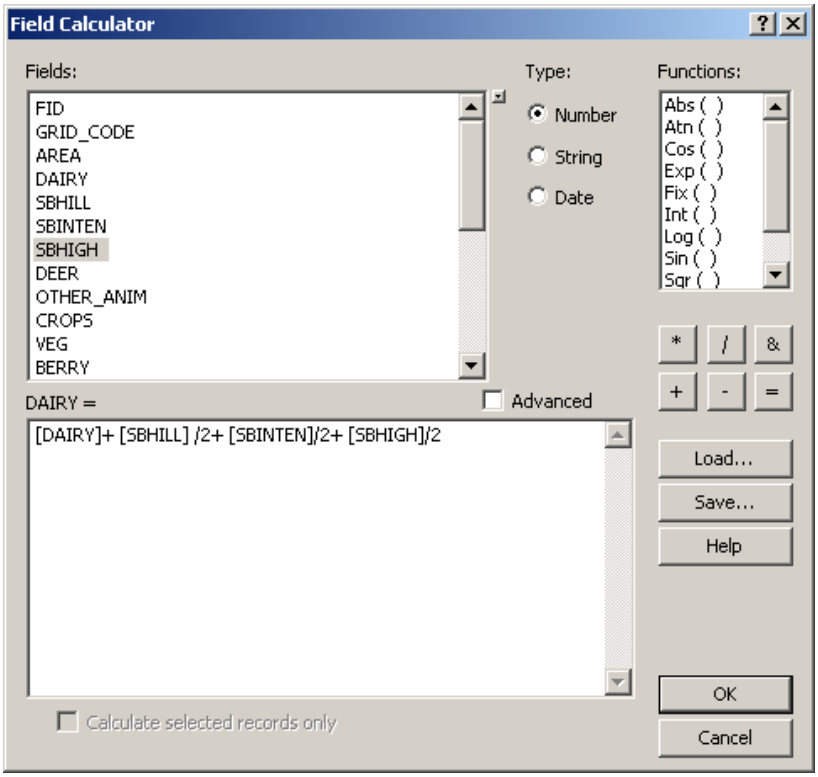
7. To use the *Field Calculator* to make blanket changes, right click on the field title cell of the first land use to manipulated (in this case DAIRY) to bring up the editing options list and select *Field Calculator*.



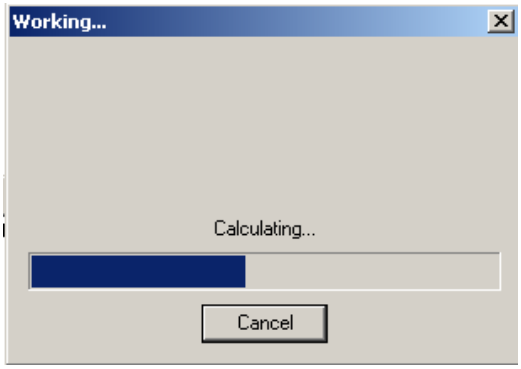
8. Enter the calculation into the *Field Calculator* window. This example increases dairying at the expense of half the sheep and beef farming requires the following calculation:

$$dairy_{new} = dairy_{old} + \frac{(sheep\ and\ beef_{old})}{2}$$

The form of this equation in the *Field Calculator* is given below.

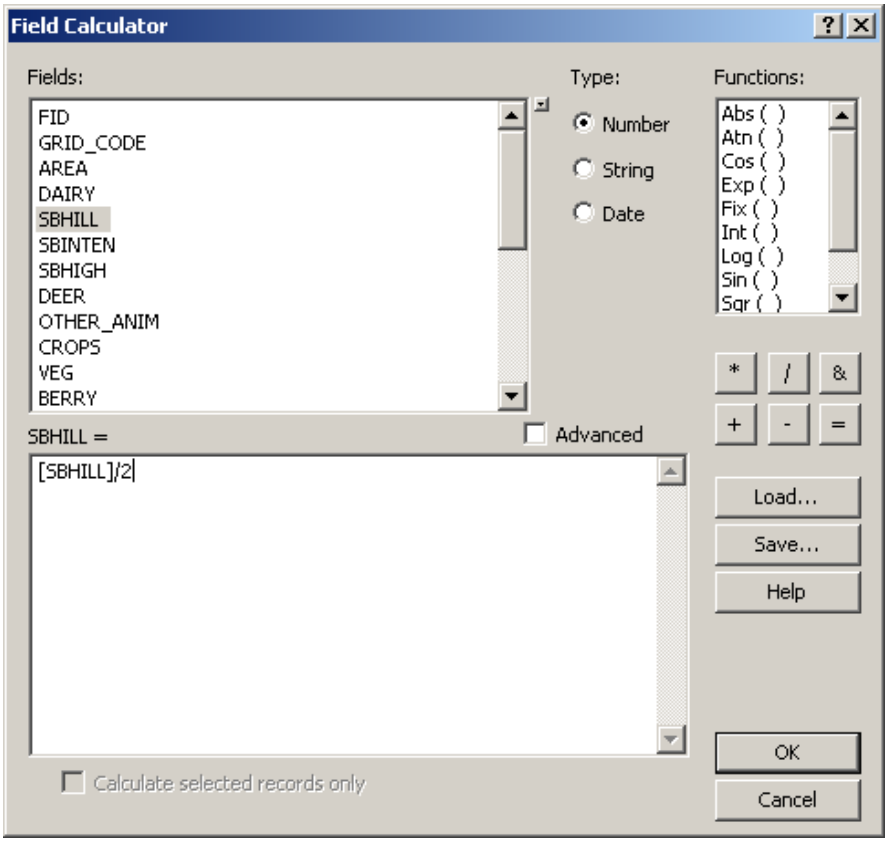


Click *OK*. The calculation progress will be indicated. Once complete, the field will be updated.



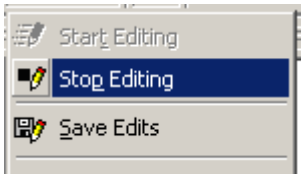
9. When doing calculations, ensure that the total land use remains at 100%. In this case, the sheep and beef columns (SBHILL, SBINTEN and SBHIGH) must be halved. Right click the sheep and beef fields in turn to use the *Field Calculator* to reduce these covers according to the formula:

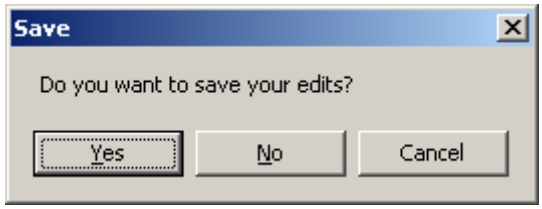
$$sheep\ and\ beef_{new} = \frac{(sheep\ and\ beef_{old})}{2}$$



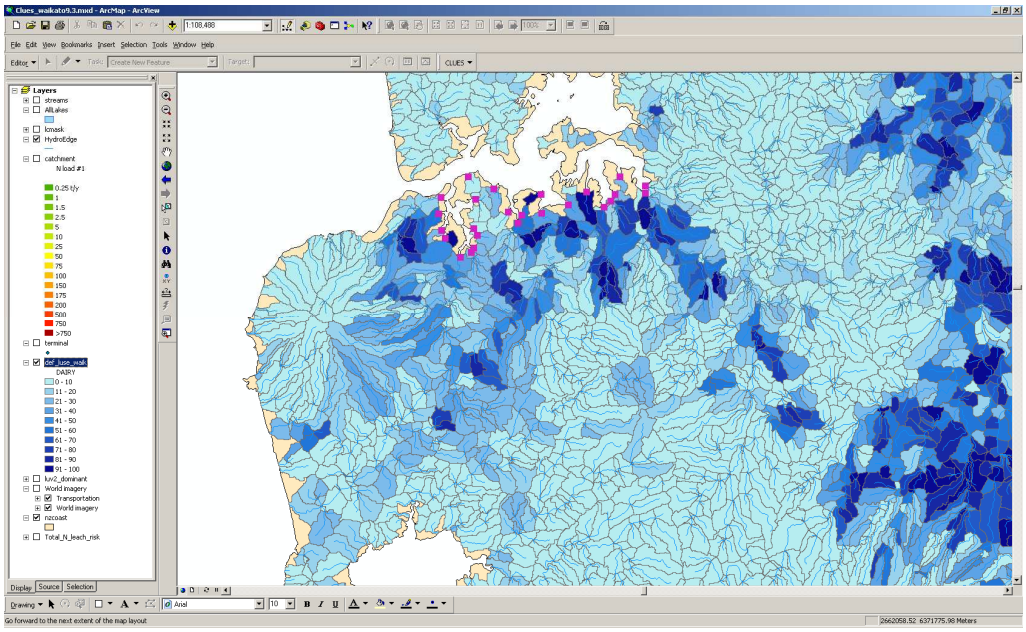
Once calculations are complete, close the attribute table.

10. If you have made calculations in edit mode, end the editing session by clicking *Stop Editing* on the *Editor* toolbar and click *Yes* at the save prompt. This step can take some time depending on the number of edits made.

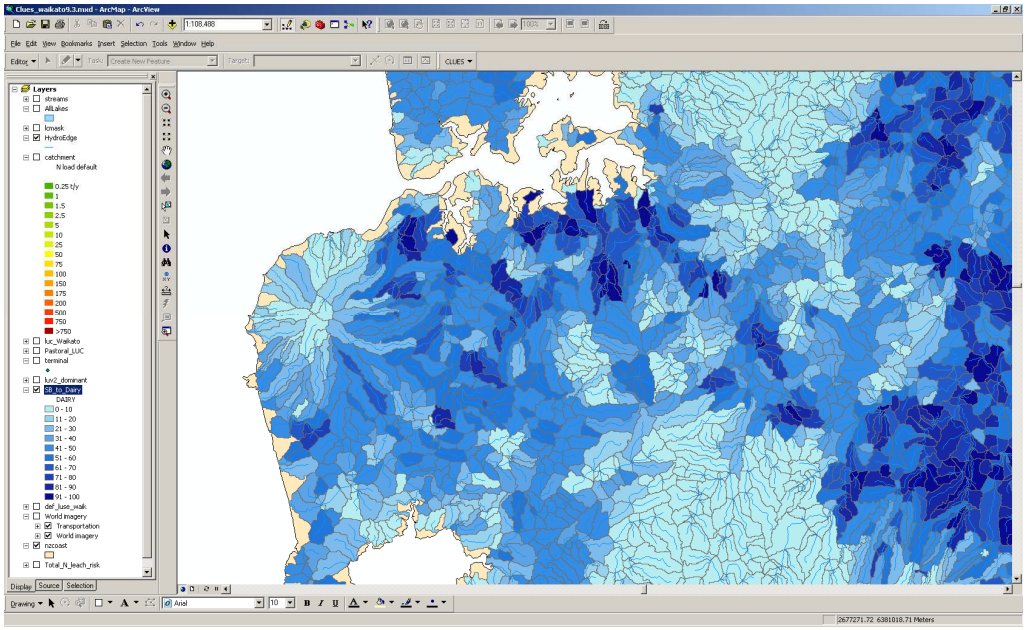




In this scenario, the proportion of dairying has increased substantially.



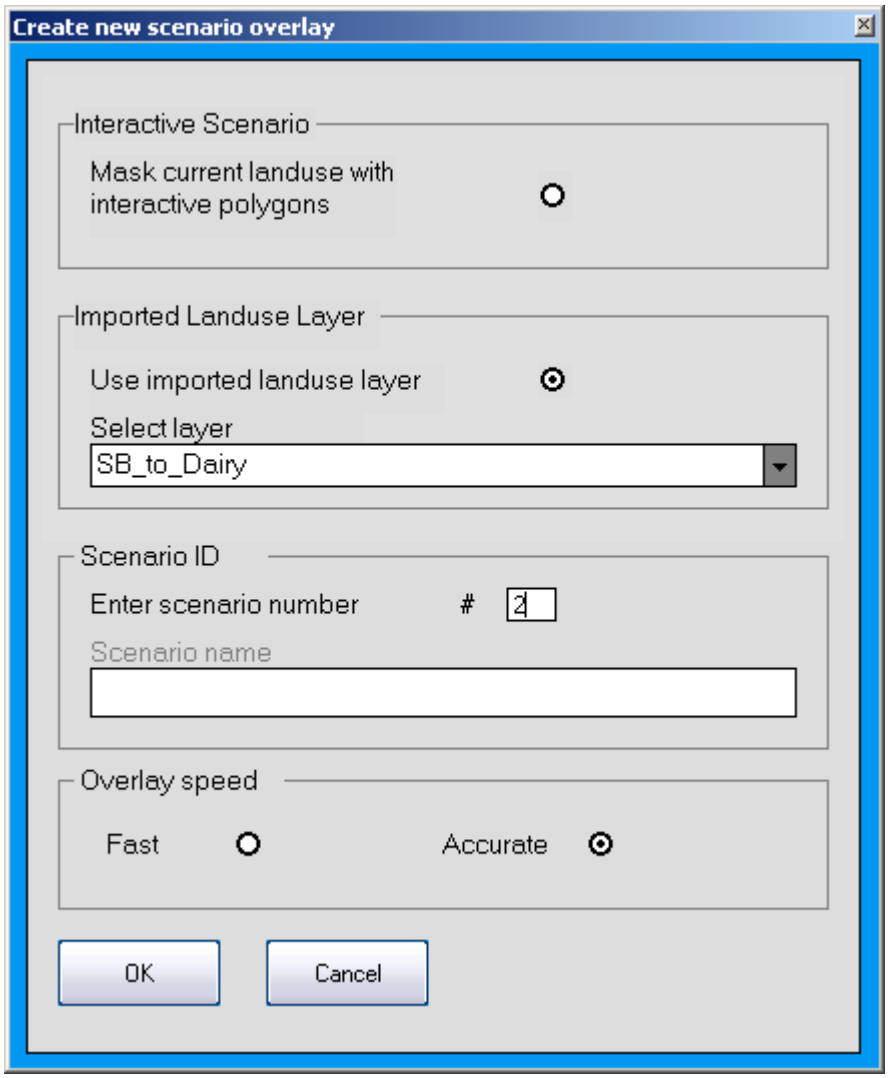
Before: Proportion of dairying in the Waikato default land use template *def_luse_waik*.



After: Proportion of dairying in the new land use layer *SB_to_dairy*

11. The scenario can now be created from the adjusted land use layer by clicking the *Overlay Scenario* button under the *Create Scenario* tools.

In the *Create new scenario overlay* dialogue box, check the *Imported Land use Layer* radio button and select the land use layer from the *Select layer* drop-down menu.



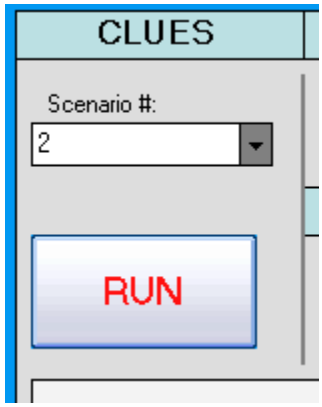
Assign a scenario number from the *Scenario ID* options (2 is used in this example) and select the *Overlay speed* radio button required.

NOTE: there are two overlay modes; *Fast* and *Accurate*. *Fast* mode creates a scenario with a spatial resolution of 100 m (1 ha) while *Accurate* mode creates a scenario with a spatial resolution of 30 m (0.09 ha). Choosing *Accurate* will result in a longer overlay time.

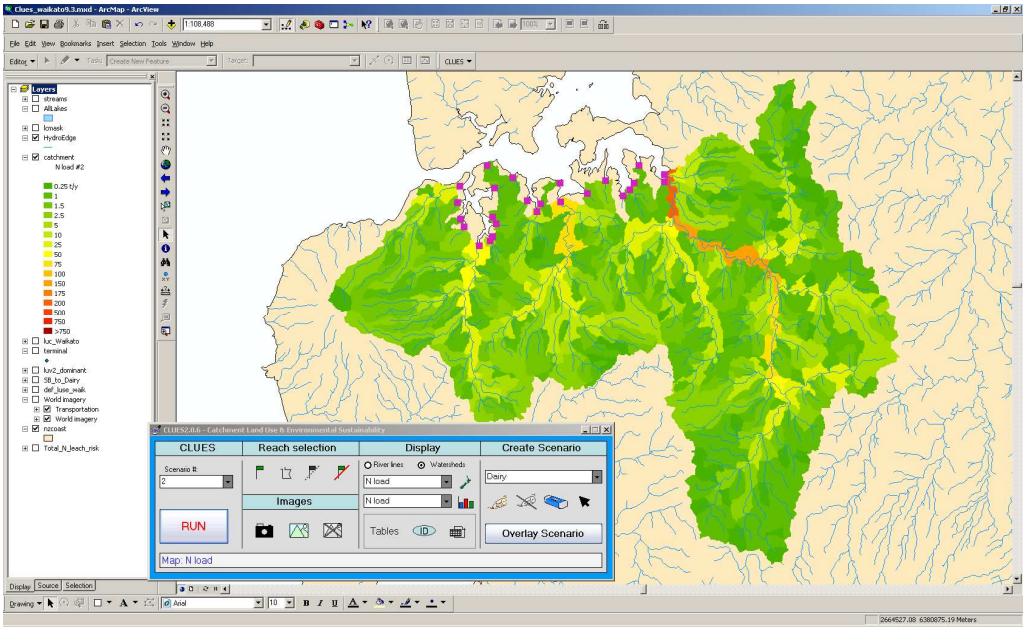
AVOID SWITCHING TO ANOTHER PROGRAM WHILE THE SCENARIO OVERLAY DIALOGUE BOX IS OPEN—THIS CAN CAUSE ArcGIS TO CRASH.

The overlay progress will be indicated in the ArcGIS status bar. Click *OK* at the prompt. This step can take some time (have a coffee break)!

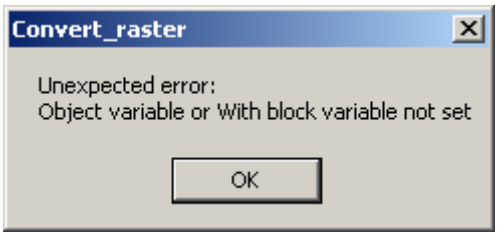
12. The CLUES modelling framework can now be run for the new scenario by selecting the relevant scenario number from the *Scenario* #drop-down menu and clicking the *RUN* button under the CLUES tools.



NOTE that the legend in the *TOC* has been updated to NLOAD #2.



TROUBLE SHOOTING: When I try to overlay, I get this error message:



This error means that CLUES cannot find the layer to overlay the scenario. The layer must be saved in the regional CLUES folder with the map document. Check the layer source in the *Properties* window to see that the layer has the correct directory pathway. It may have been saved to a different folder (ArcGIS automatically saves to the last location opened) during the export from the default template. If the layer has not been saved in the regional CLUES folder:

1. Remove the layer from the *TOC* (right click on layer and select *Remove*).
2. Move the layer shape file in ArcCatalog to the regional CLUES folder
3. Use the *Add data* tool to add the layer back to the map document.
4. Retry the overlay.

6.2.2 Example 2: Changing land use for a selection of land use polygons

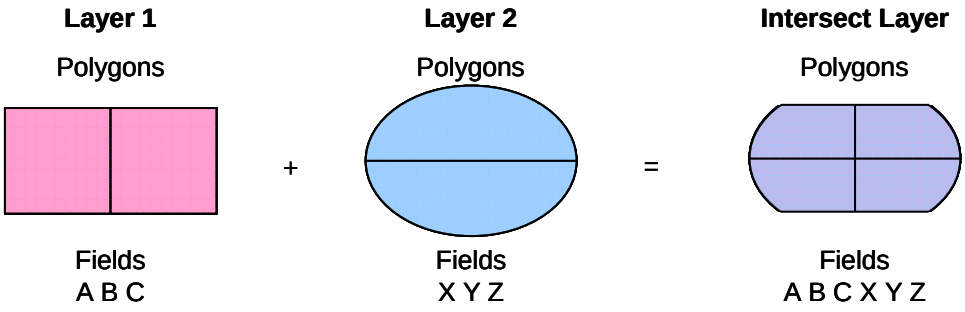
The basic method for altering the default land use in a layer given above can be applied to a selection of polygons using standard ArcGIS selection tools. Selections of land use polygons can be made manually either in the map display (the ArcGIS selection tool icon must be activated) or attribute table (click on the grey pad to the left of the polygon fields) or automatically using the ArcGIS tools for selecting polygons by attributes or location. Once a selection has been made, the land-use cells can be altered manually in edit mode, if the number of sub-catchments to be altered is small, or automatically using the *Field Calculator*.

Polygon selection within the land use layer on the basis of attributes or location does not need to be restricted to information held in the layers provided with CLUES 2.0.6. Reference layers can be added to the map document to aid scenario creation. The

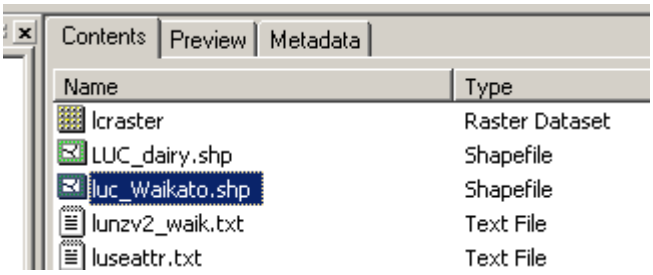
example below uses the ArcGIS *Intersect* and *Selection* tools to create a new land use scenario from the default template with reference to an imported layer.

In this example the land use capability (LUC), from the Land Resource Inventory, for Waikato (*luc_Waikato.shp*)[4] is imported as the reference layer. The scenario reallocates all land uses, with the exception of native forest and urban areas, to dairying in areas suitable for pasture. There are eight LUC classes of rural land use, four of which (Classes I to IV) are considered suitable for intensive pastoral agricultural use. As the *luc_Waikato* polygons do not have the same boundaries as the sub-catchments in the *def_luse_waik* layer, the two layers are first *intersected* to create a new layer, *Pastoral_LUC.shp*, which has the polygon boundaries and attribute fields of both layers (see the conceptual diagram below). Carrying out an intersect refines selection for scenario building ensuring that only areas with land suitable for pastoral land use are altered. The intersect tool also allows polygon selection to be made directly from the new land use layer. The land use in the selected polygons is then changed using the *Field Calculator*.

Conceptual diagram of the ArcGIS *intersect* tool:

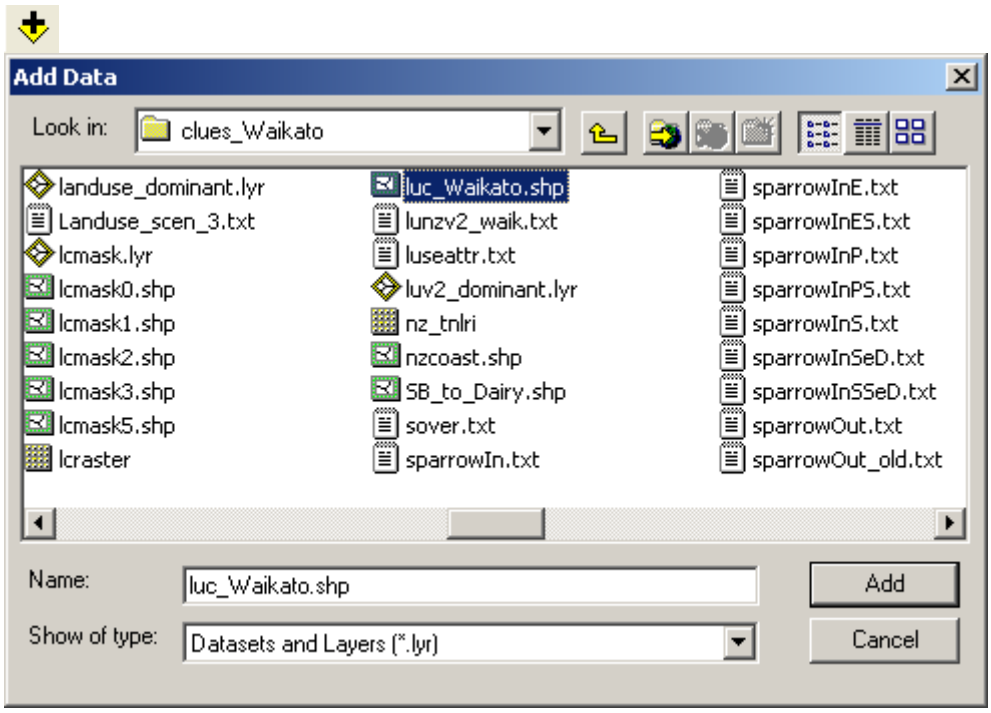


1. In ArcCatalog, copy the reference layer to be used for sub-catchment selection (in this case the Waikato LUC layer *luc_Waikato.shp*) into the CLUES 2.0.6 folder—this step is optional, but keeps all the shape files in the map document in one place.

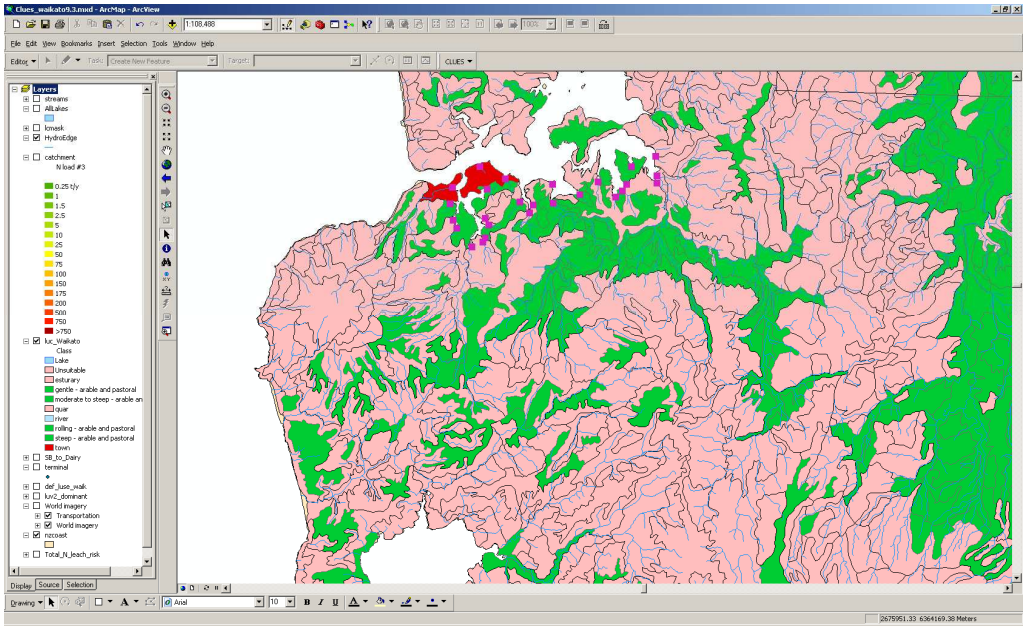


[4] The GIS shape file for LUC classes is from the Landcare Research New Zealand Land Resource Inventory (NZLRI), details can be found at http://www.landcareresearch.co.nz/databases/nzlri.asp

2. Click the *Add data* icon to add the reference layer.

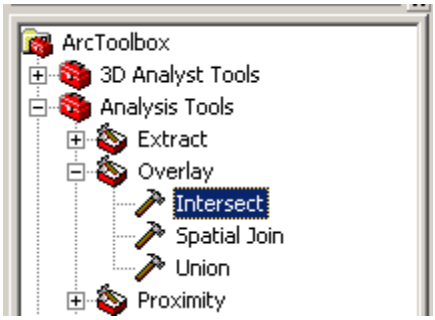


The reference layer should now be displayed. Here the layer has been moved down the *TOC* and the symbology has been altered to show pastoral land (Classes I to IV) in green, Raglan is red and other land use classes in pink.

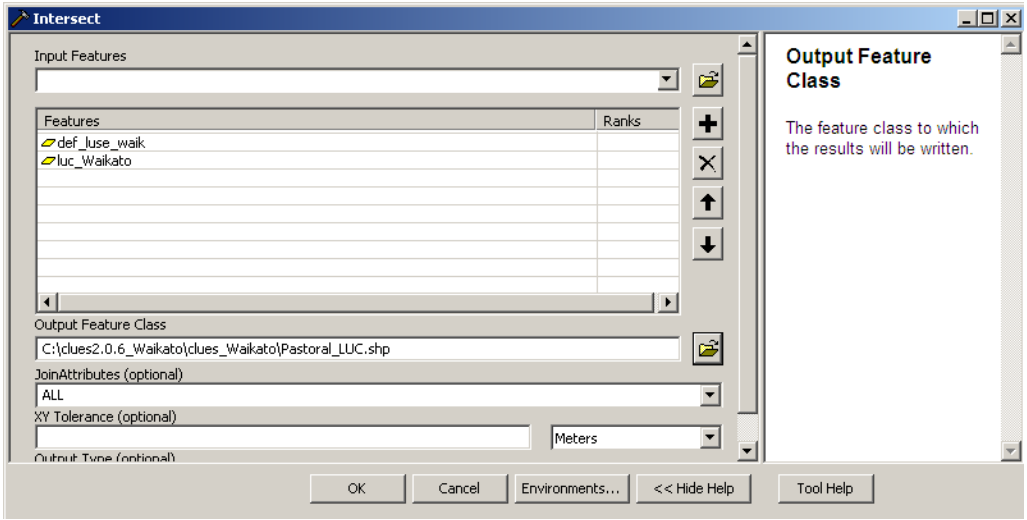


5. Use the ArcGIS Intersect tool to create the new land use scenario layer from the template and reference layers. Here the *def_luse_waik* layer has been intersected by the *luc_Waikato* layer to form a layer called *Pastoral_LUC*. This layer has the boundaries and attributes of both layers.

   Click the *ArcToolbox* icon on the ArcGIS *Standard* toolbar to open the toolbox and select the *Intersect* tool under the *Analyst Tools/Overlay* menu.

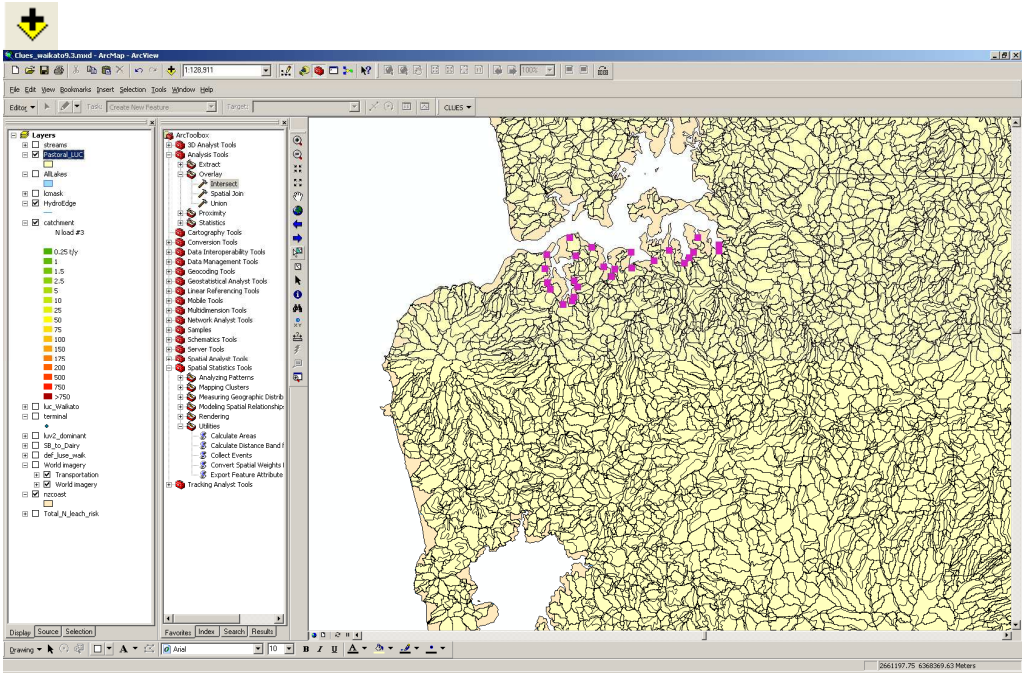


   Use the *Input Features* drop-down menu to add the template and reference layers in turn. Make sure the intersect layer has a suitable name (here *Pastoral_LUC.shp*) and is saved into the regional CLUES folder.

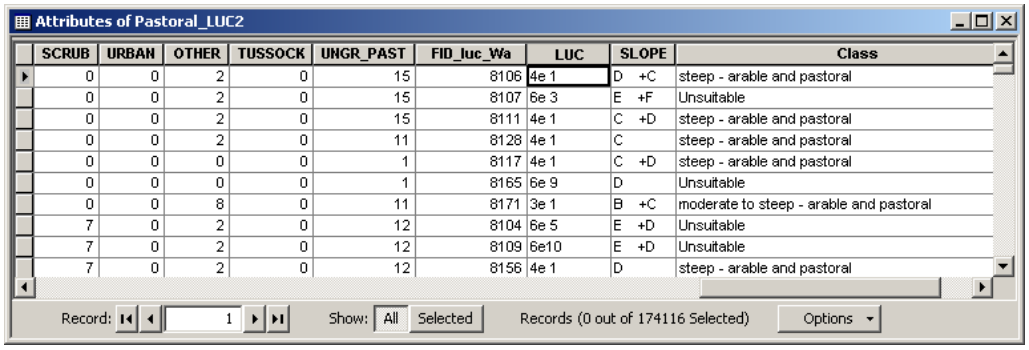


   ArcGIS will display the Intersect progress.

   Once complete, the intersected layer can be added to the map document using the *Add data* icon and selecting the layer shape file.



6. The intersect layer (*Pastoral_LUC*) has the polygon boundaries and attribute fields of the two input layers with each polygon assigned the values of its parent polygons (*def_luse_waik* and *luc_Waikato*).



Attributes of Pastoral_LUC2

SCRUB	URBAN	OTHER	TUSSOCK	UNGR_PAST	FID_luc_Wa	LUC	SLOPE	Class
0	0	2	0	15	8106	4e 1	D +C	steep - arable and pastoral
0	0	2	0	15	8107	6e 3	E +F	Unsuitable
0	0	2	0	15	8111	4e 1	C +D	steep - arable and pastoral
0	0	2	0	11	8128	4e 1	C	steep - arable and pastoral
0	0	0	0	1	8117	4e 1	C +D	steep - arable and pastoral
0	0	0	0	1	8165	6e 9	D	Unsuitable
0	0	8	0	11	8171	3e 1	B +C	moderate to steep - arable and pastoral
7	0	2	0	12	8104	6e 5	E +D	Unsuitable
7	0	2	0	12	8109	6e10	E +D	Unsuitable
7	0	2	0	12	8156	4e 1	D	steep - arable and pastoral

Record: 1 Show: All Selected Records (0 out of 174116 Selected) Options

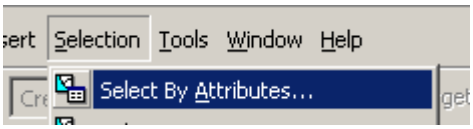
These fields are not automatically updated. For the AREA and GRID_CODE fields from the land use template, this can cause problems for later interpretation and scenario building.

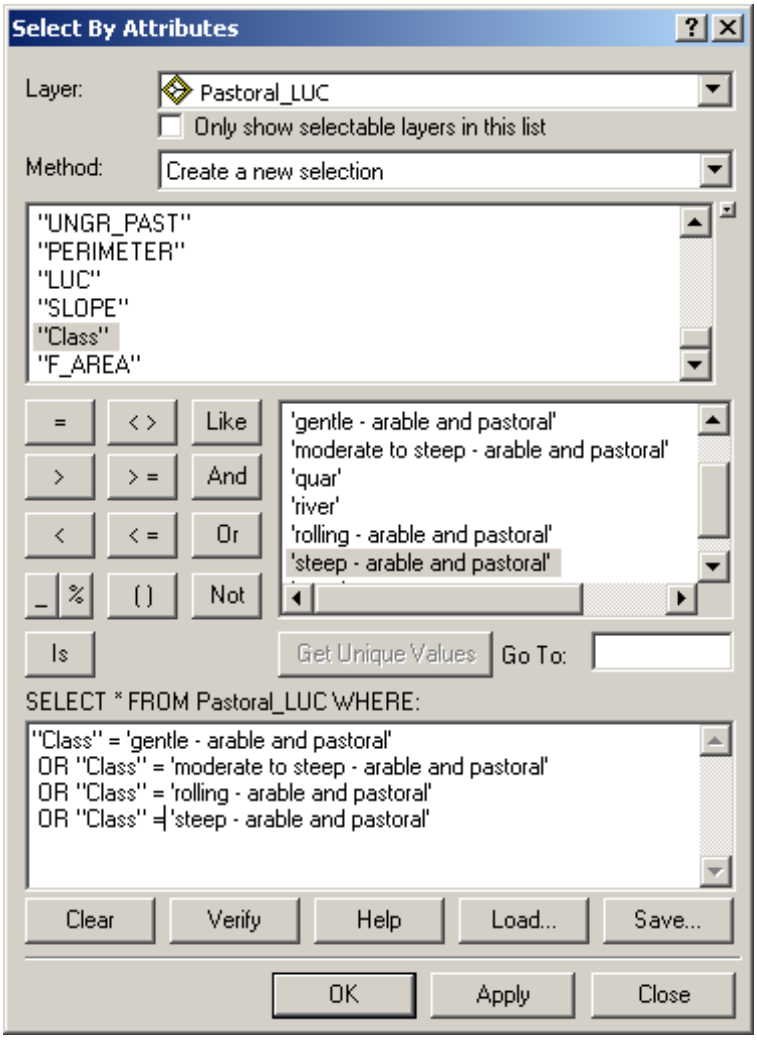
For example, the GRID_CODE field is the unique identifier for the entire sub-catchment in the *def_luse_region* layer; when intersected, there can be several polygons with the same GRID_CODE. This field needs to be updated so that each polygon has a unique value. The easiest way to do this is to use the *Field Calculator* to set the code to FID+1 (the FID field is an identifier automatically created by ArcGIS).

On the other hand, while it is possible to update the area using ArcGIS tools, the field has been provided for reference only and is not needed for scenario building, hence it does not need to be updated to create a new scenario. In fact, this field can safely be deleted without affecting the overlay process.

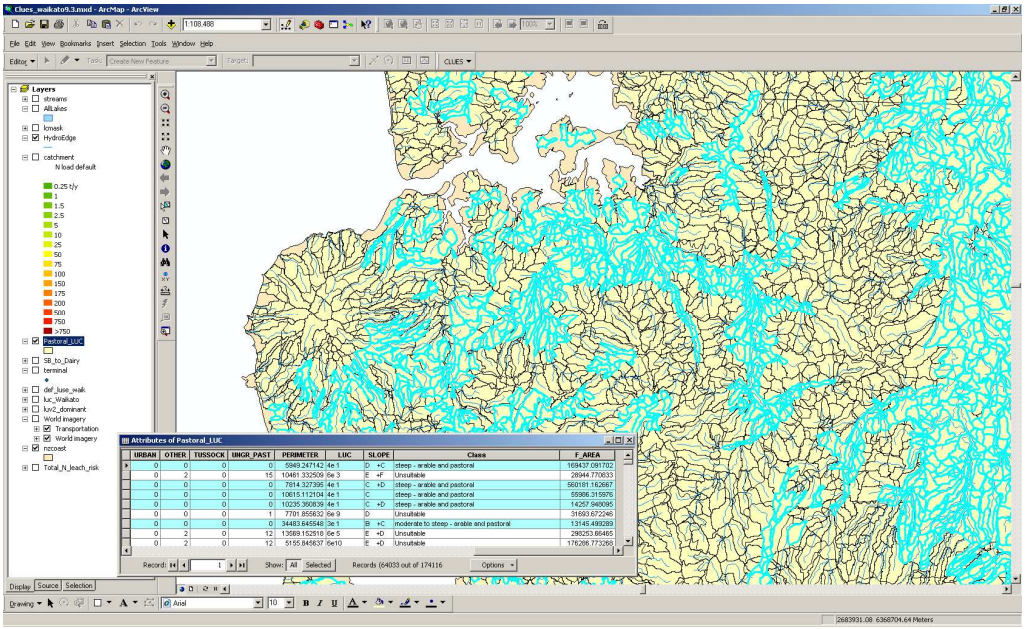
Once the GRID_CODE is updated, the new layer is now ready for polygon selection and land-use adjustment.

7. Use the ArcGIS selection tool *Select by Attributes* under the *Selection* menu to select those polygons from the new land use layer (here *Pastoral_LUC*) which satisfy the conditions for the scenario (here LUC Classes suitable for pastoral use).



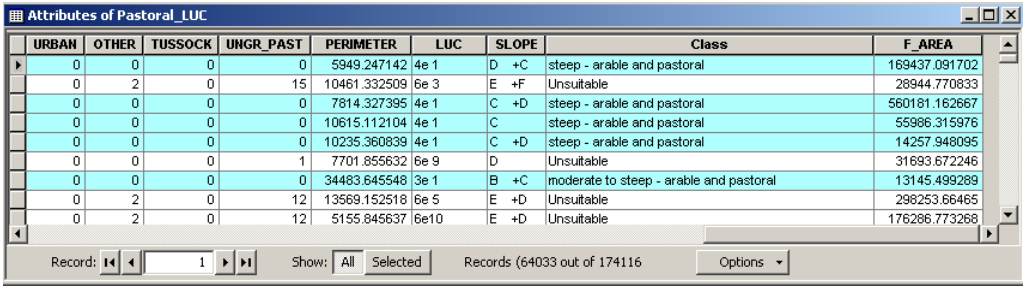


Click *OK*. The selected polygons for land use change are now highlighted by ArcGIS on both the display and in the attribute table.

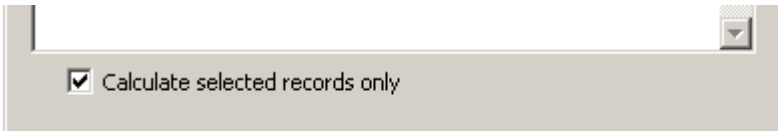


8. Use the *Field Calculator* to adjust each field for the selected records. Either make sure that the *Field Calculator* option is set to *calculate selected records only* or click the *Selected* button at the bottom of the attribute table. In the latter case, the attribute table will list only the selected polygons and automatically ensures that field calculations are made these selected polygons.

   Either

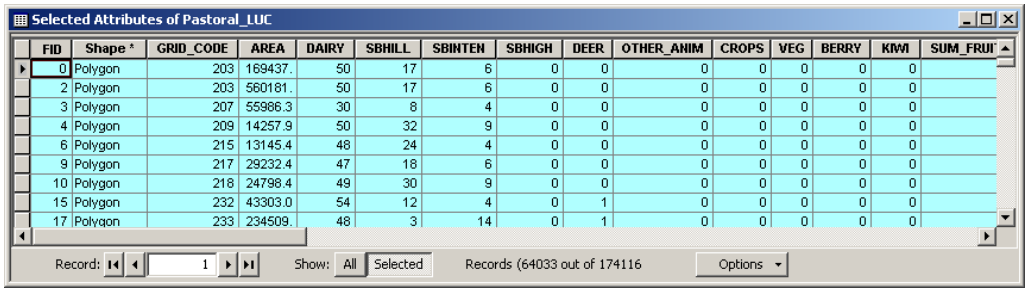


Attribute table

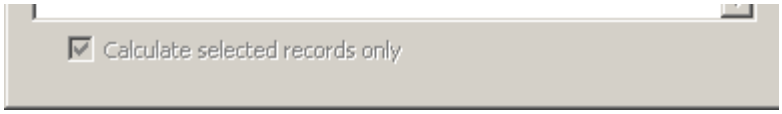


Field Calculator

or

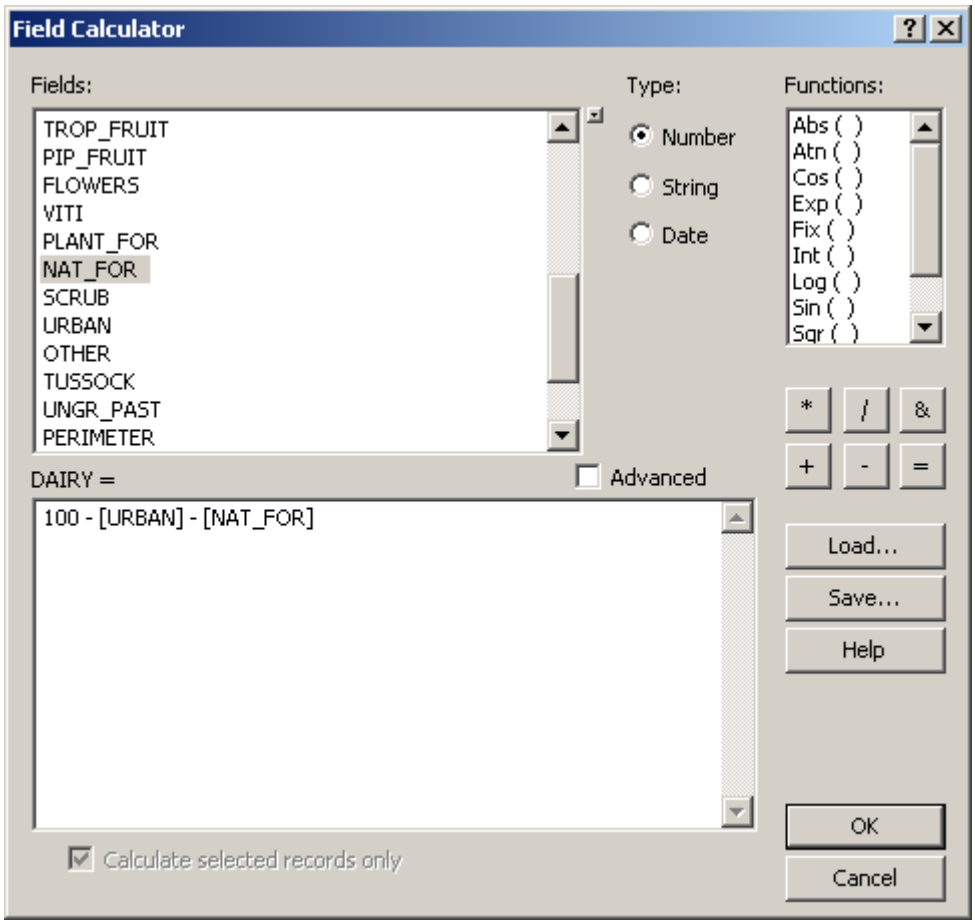


Attribute table



Field Calculator

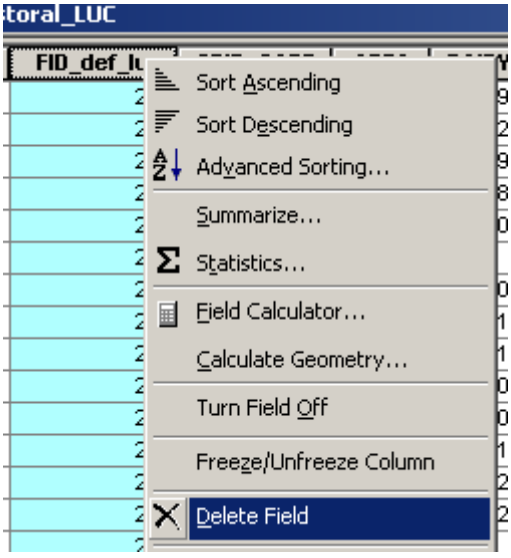
In this example, all land uses with the exception of native forest and urban will be converted to dairying. It is recommended that the adjustments be made in editing mode (see details in Section 6.2.1) for safety as changes made with the *Field Calculator* outside editing mode cannot be reversed.



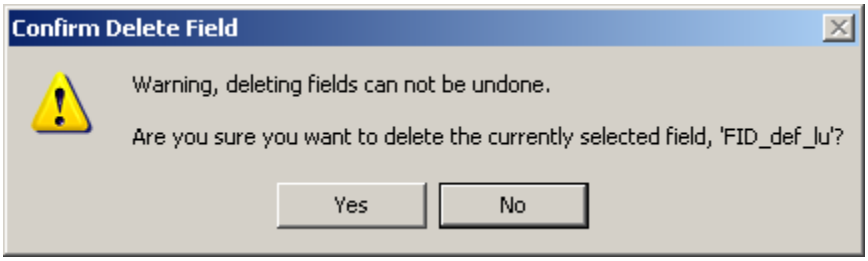
The total land use for each polygon should total 100%. Here the percentage for other land uses, with the exception of native forest and urban, have been set to zero, e.g., SBHILL (hill country sheep and beef).

If you are in edit model, stop editing and save changes once all changes have been made.

9. Clear the selection and show all polygons in the attribute table. Fields not required for the scenario overlay (e.g., AREA, the FID_def_lu field and those associated with the reference layer) can be deleted (right click on field for options) to reduce the size of the attribute table.

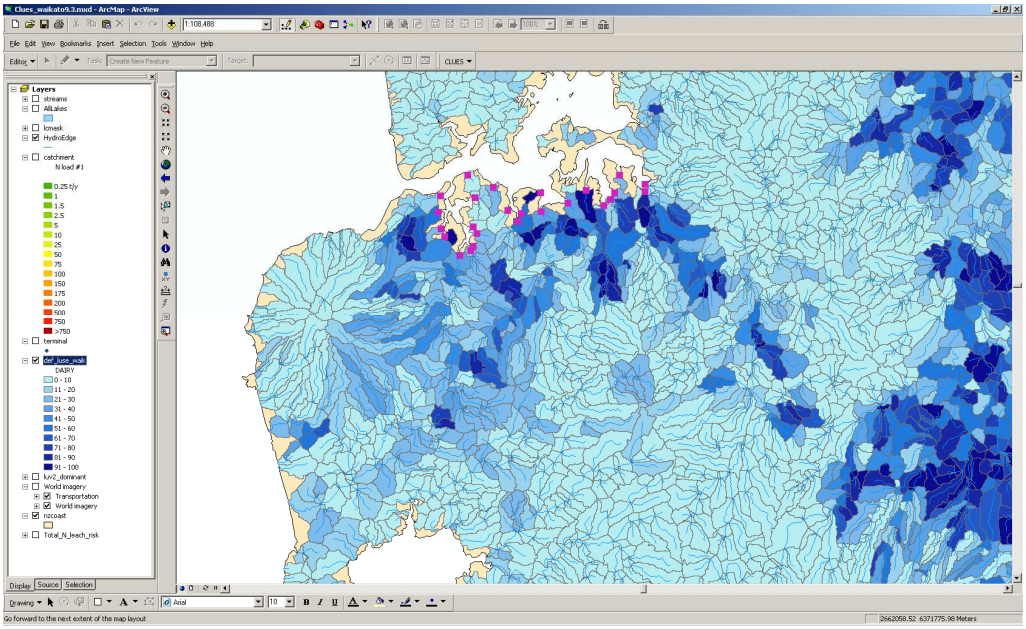


ArcGIS will ask for a confirmation for each field to be deleted.

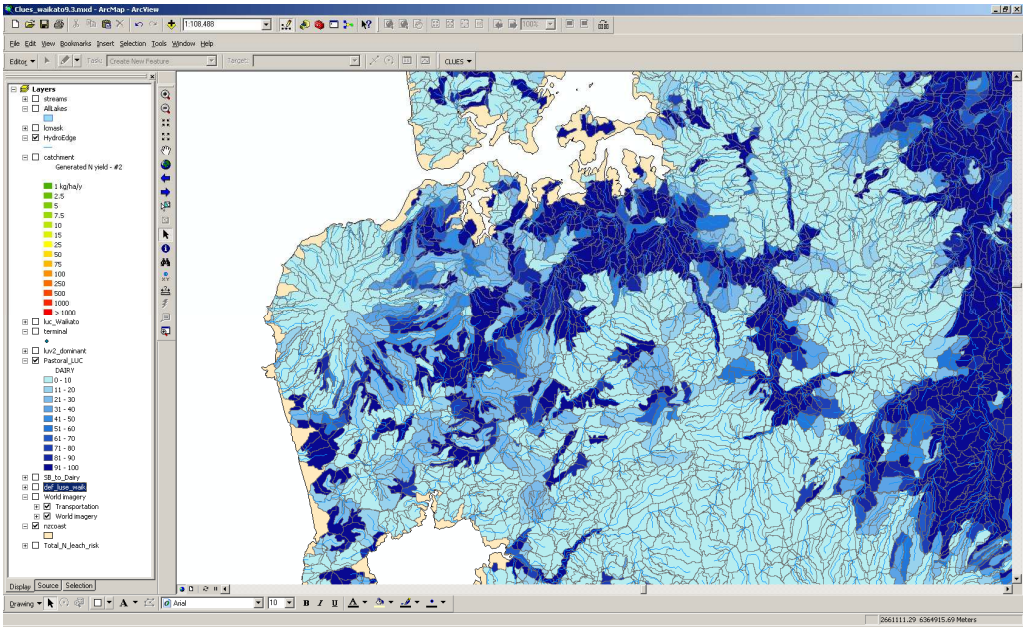


Check that the land use scenario layer has the same fields (with or without the AREA field). The scenario can now be created from the land-use layer.

Note that the proportion of dairying in this scenario has increased substantially for the area to be simulated



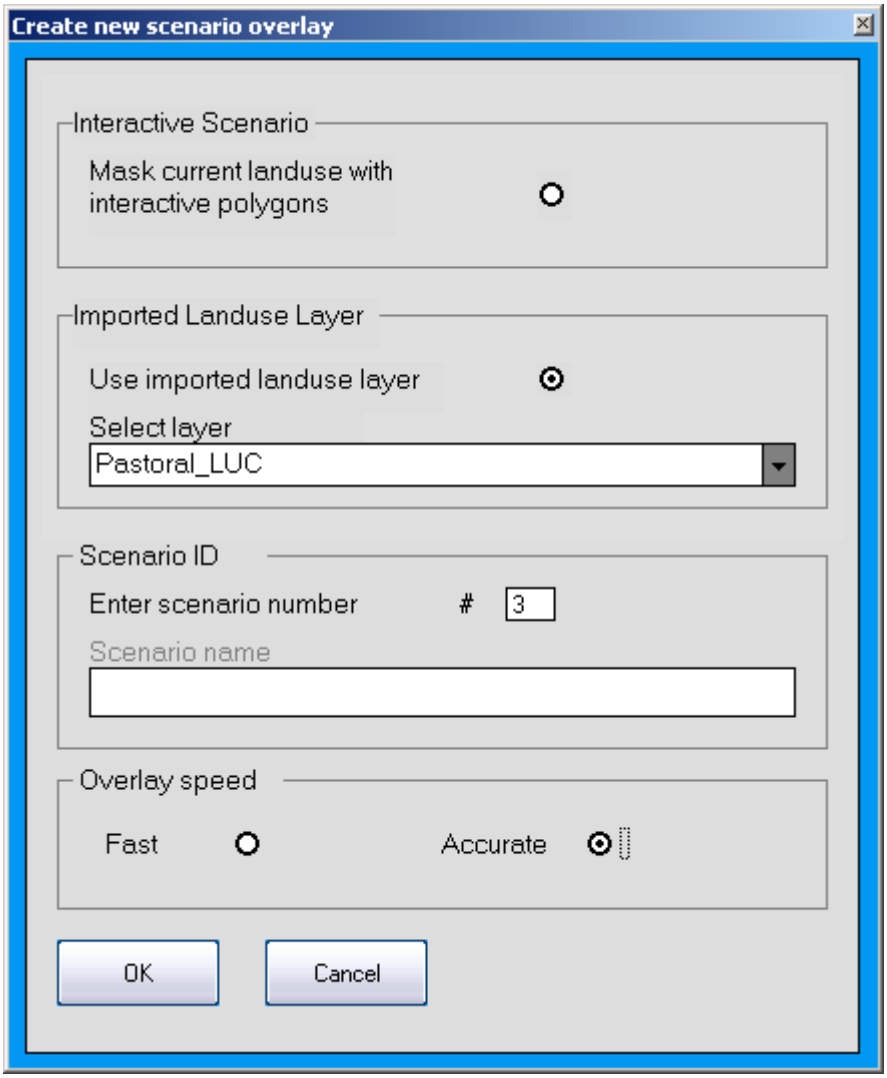
Before: Proportion of dairying in the mock default land use layer *def_luse_waik*.



After: Proportion of dairying in the new land use layer *Pastoral_LUC*

9. Click the *Overlay Scenario* button under the *Create Scenario* tools.

In the *Create new scenario overlay* dialogue box, check the *Imported Land use Layer* radio button and select the land use layer from the *Select layer* drop-down menu.



Assign a scenario number from the *Scenario ID* options (3 is used in this example) and select the *Overlay speed* radio button required.

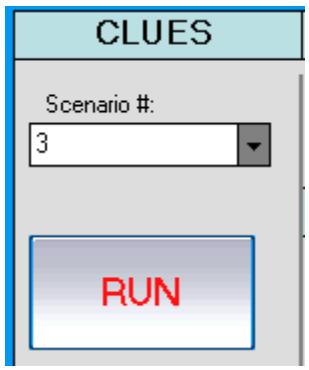
NOTE: there are two overlay modes; *Fast* and Accurate. *Fast* mode creates a scenario with a spatial resolution of 100 m (1 ha) while *Accurate* mode creates

a scenario with a spatial resolution of 30 m (0.09 ha). Choosing *Accurate* will result in a longer overlay time.

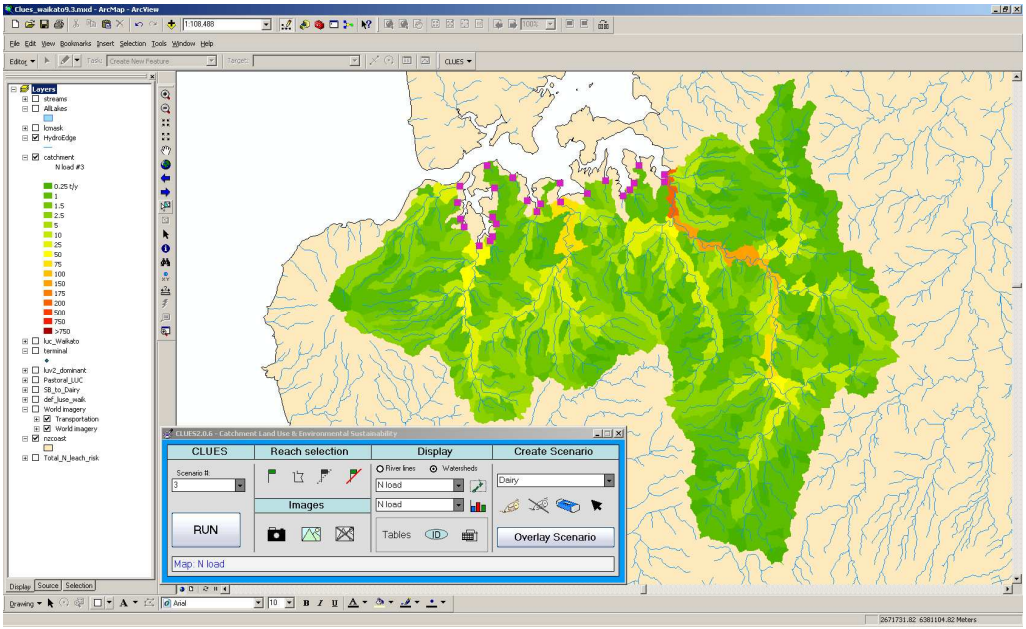
AVOID SWITCHING TO ANOTHER PROGRAM WHILE THE SCENARIO OVERLAY DIALOGUE BOX IS OPEN—THIS CAN CAUSE ArcGIS TO CRASH.

The overlay progress will be indicated in the ArcGIS status bar. Click *OK* at the prompt. This step can take some time (have a coffee break)!

10. The CLUES modelling framework can now be run for the new scenario by selecting the relevant scenario number from the *Scenario* #drop-down menu and clicking the *RUN* button.



NOTE that the legend in the *TOC* has been updated to NLOAD #3.

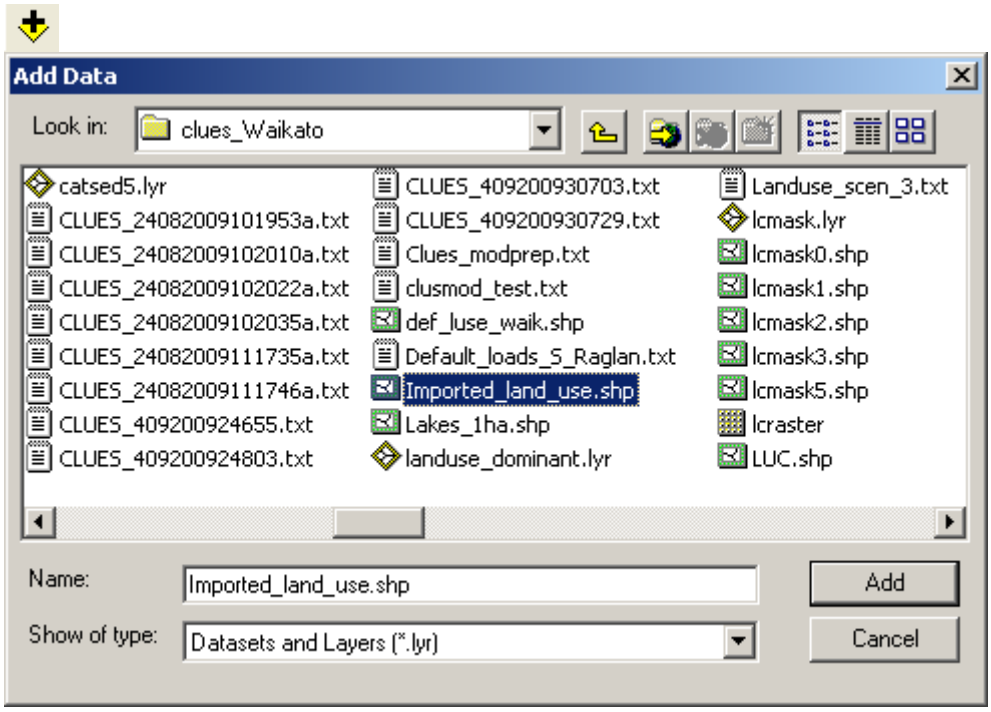


6.3 Imported Land use Layers

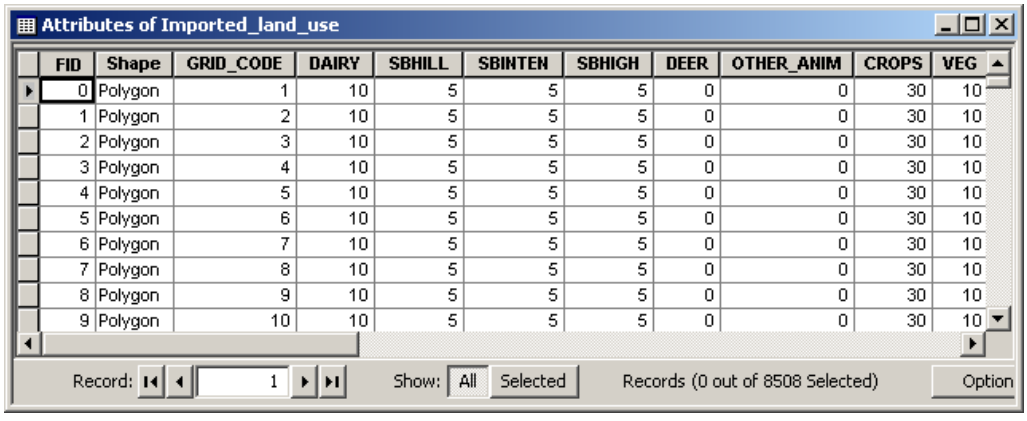
Land use scenario polygon shape files can be imported into the CLUES 2.0.6 map document for scenario creation provided they contain the same attribute fields (with the exception of the AREA field which can be omitted) as the default land use template (*def_luse_region*) in the same order. Users will need to have intermediate to advanced GIS skills. In this example, a new layer called *Imported_new_land_use.shp* has been created in order to illustrate the importation method—this layer is not available to users and is for demonstration purposes only.

1. Use ArcCatalog to copy the imported land use layer into the CLUES regional folder. The layer needs to be in this folder for scenario creation.

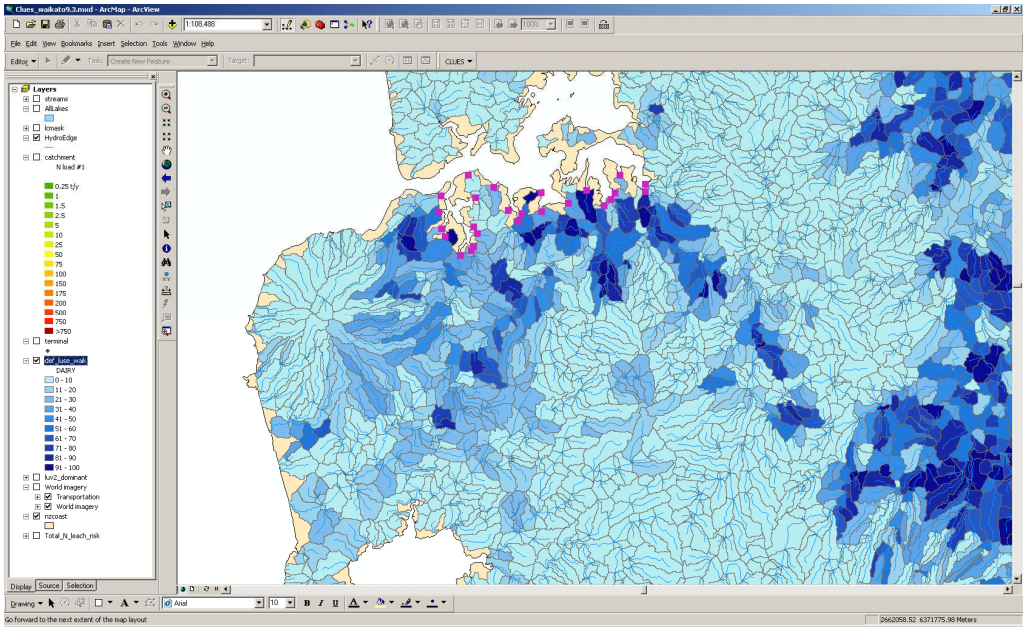
2. Click the *Add data* icon to add the scenario shape file. TIP: copy the shape file to the CLUES 2.0.6 directory using ArcCatalog so that all layers associated with the map document are in one location.



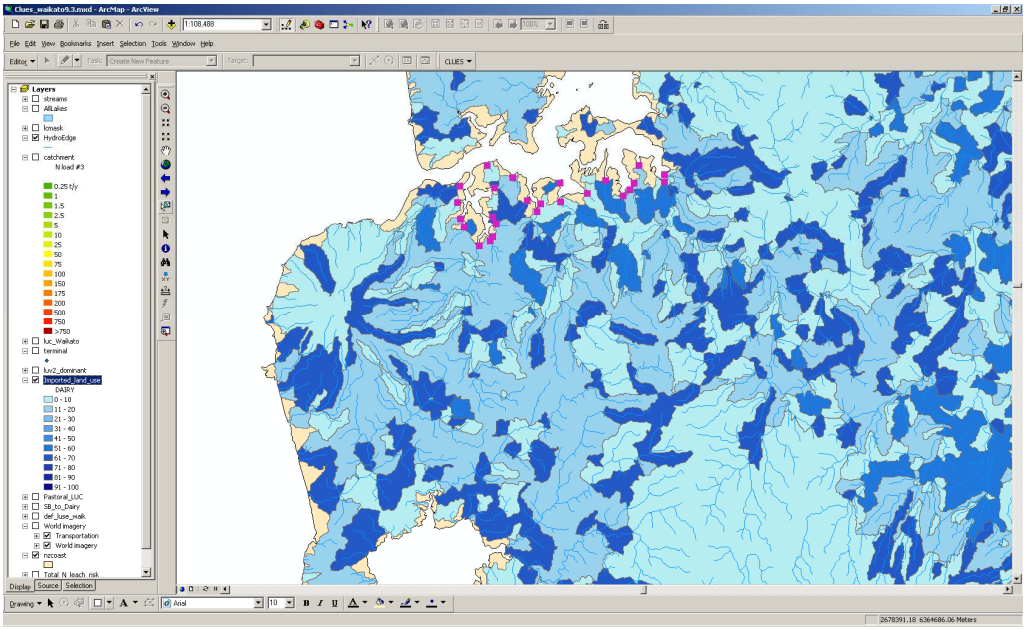
3. Check that the imported layer has the land use attributes required for CLUES 2.0.6 (i.e., FID, SHAPE, GRID_CODE, DAIRY …… UNGR_PAST). The sum of the land use attributes must be 100% for each polygon. The layer must have a GRID_CODE field (unique identity whole number—type Long) and land use proportions to function. The AREA field found in the template is for reference only and can be omitted (as in this example) from the imported layer without affecting the overlay process.



Note that the imported land use layer below differs from *def_luse_waik* layer in not only the proportion of each land use type (below Dairy farming) but also in that the polygons are not the same as the sub-catchments.

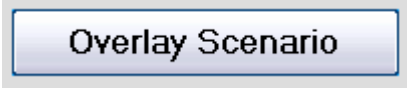


Default: Proportion of dairying in the mock default land use layer *def_luse_waik*.

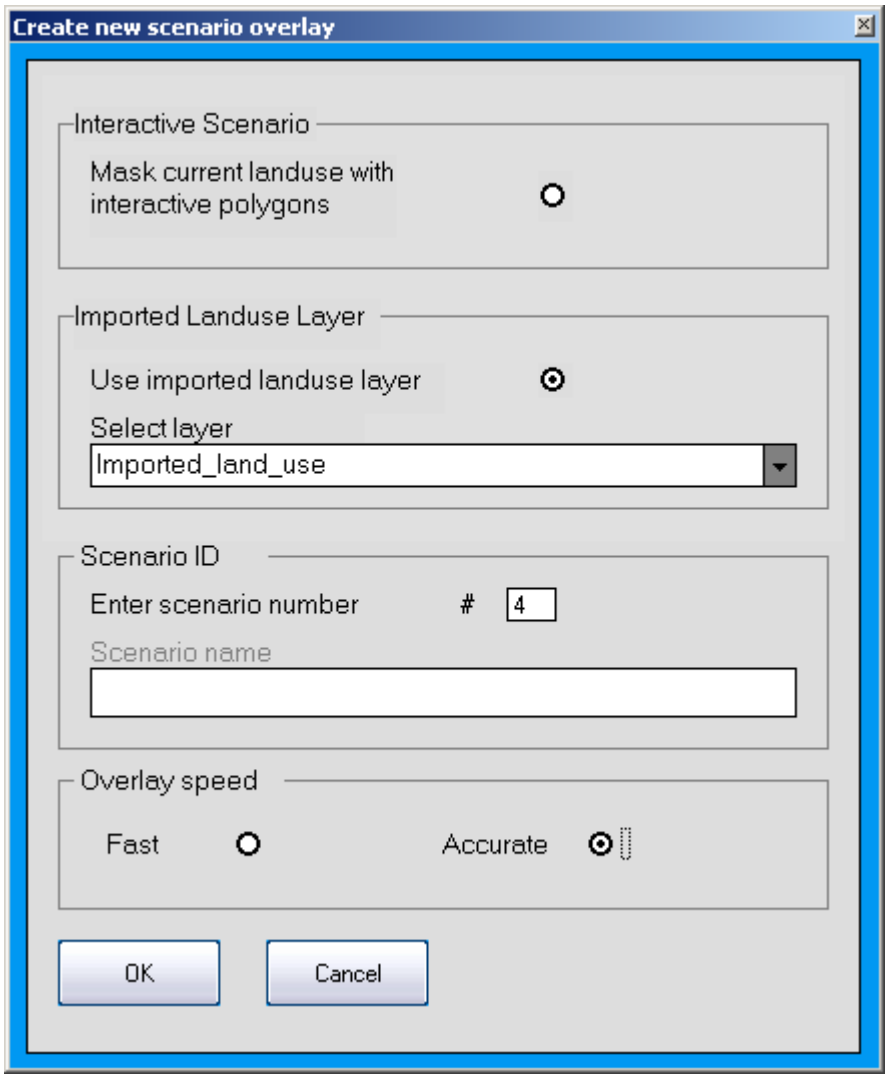


Imported land use: Proportion of dairying in the imported land-use layer.

4. Once the new land-use layer has been imported, the scenario can be created from the by clicking the *Overlay Scenario* button under the *Create Scenario* tools.



In the *Create new scenario overlay* dialogue box, check the *Imported Land use Layer* radio button and select the land use layer from the *Select layer* drop-down menu.

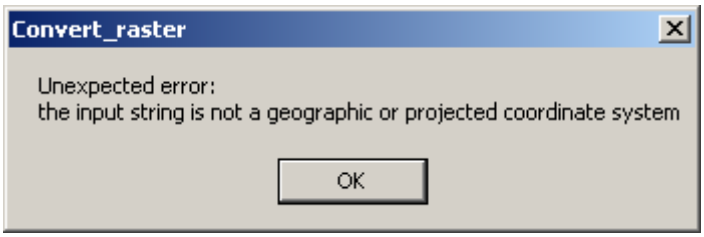


Assign a scenario number from the *Scenario ID* options (4 is used in this example) and select the *Overlay speed* radio button required.

NOTE: there are two overlay modes; *Fast* and *Accurate*. *Fast* mode creates a scenario with a spatial resolution of 100 m (1 ha) while *Accurate* mode creates a scenario with a spatial resolution of 30 m (0.09 ha). Choosing *Accurate* will result in a longer overlay time. The overlay progress will be indicated in the ArcGIS status bar. Click *OK* at the prompt. This step can take some time (have a coffee break)!

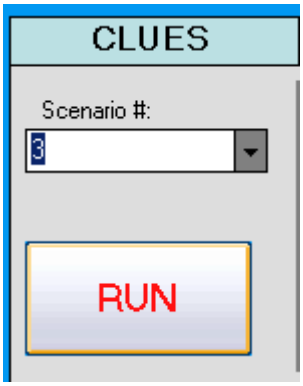
AVOID SWITCHING TO ANOTHER PROGRAM WHILE THE SCENARIO OVERLAY DIALOGUE BOX IS OPEN—THIS CAN CAUSE ArcGIS TO CRASH.

TROUBLE SHOOTING: I get errors like these when I try to overlay my imported land use layer.

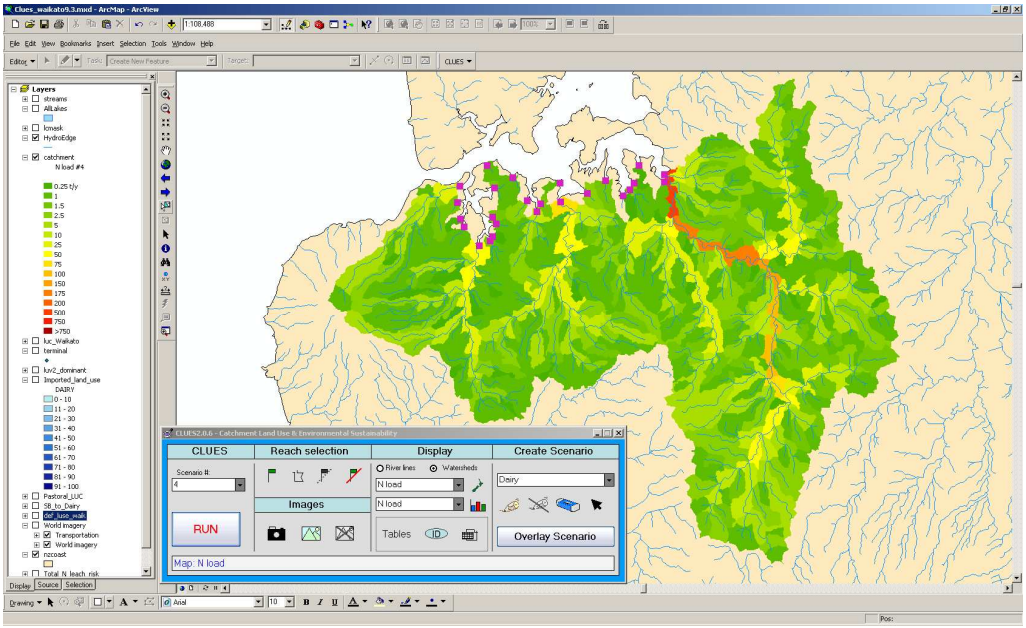


Check that your imported layer has the correct fields in correct order (see the *def_luse_region* layer) in the attribute table. The only exception is the AREA field which can me omitted.

5. The CLUES modelling framework can now be run for the new scenario by selecting the relevant scenario number from the *Scenario* #drop-down menu and clicking the *RUN* button.



NOTE that the legend in the *TOC* has been updated to NLOAD #4.



6.4 Comparing Scenario Results

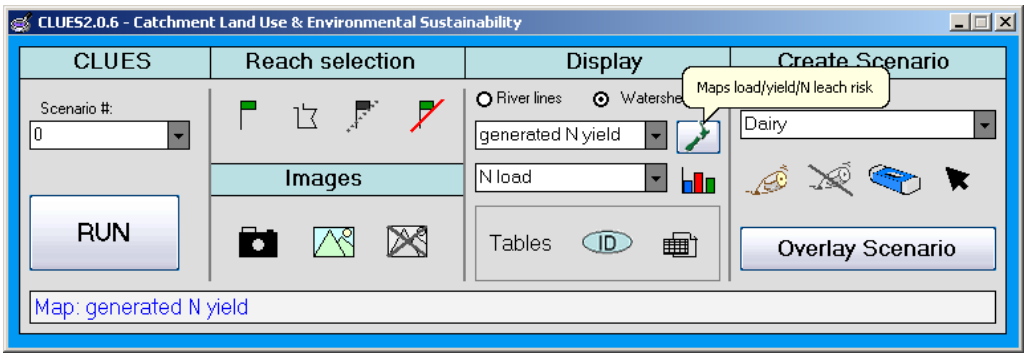
The impacts of different land use scenarios can be displayed in four ways:

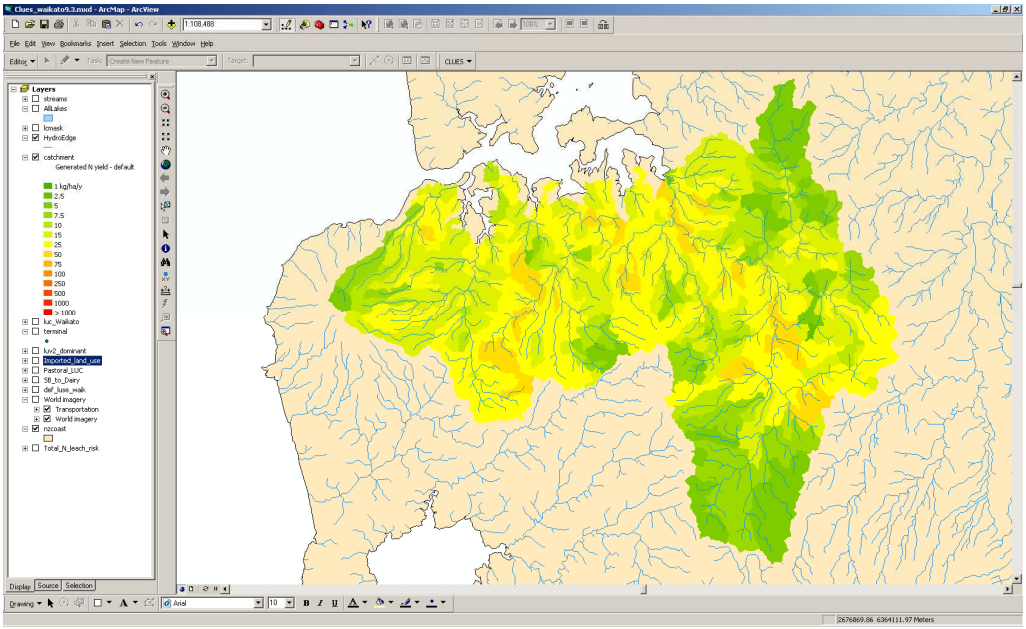
- toggling between the most recent scenario run results;
- saving and retrieving geo-referenced tiff images;
- bar charts; and
- result tables.

CLUES 2.0.6 will over-ride earlier runs for a given land use scenario, thus if the same land use scenario was used to simulate several different river reach selections, only the last selection will be mapped. For bar charts and tables, ALWAYS run CLUES 2.0.6 with both the default land use scenario (#0) and the land use change scenario(s) to be analysed for each new selection of river reaches. This will ensure that the same river reaches are present for direct comparison.

6.4.1 Toggling maps and charts

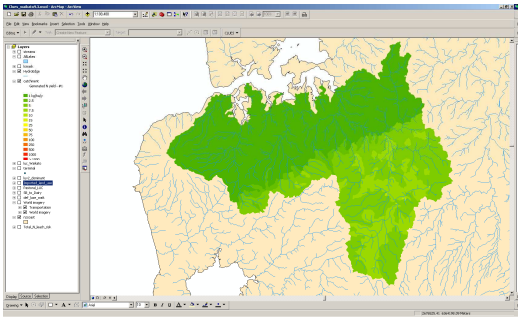
Users can toggle between the results of different land use scenarios by clicking the scenario number from the *Scenario* #drop-down menu under CLUES tools and selecting the desired map or chart under the *Display* tools. For example, clicking the *Map* icon with the set-up below will display the generated N yield for default land use, *Scenario* #0.



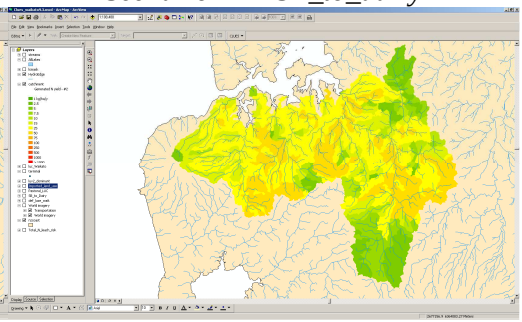


By changing the *Scenario #*, the results for the latest runs for each of the respective scenarios can be mapped and compared. Here, the generated N yield maps for the four scenarios created above are compared for the catchments south of Raglan Harbour. Note, these runs are for the same river reach selection, to compare maps for different river reaches or to retrieve results, use the CLUES 2.0.6 imaging tools.

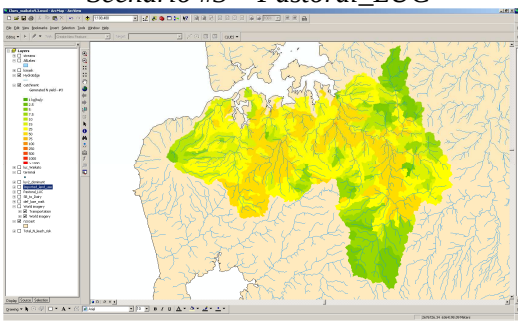
Scenario #1—Interactive sketch



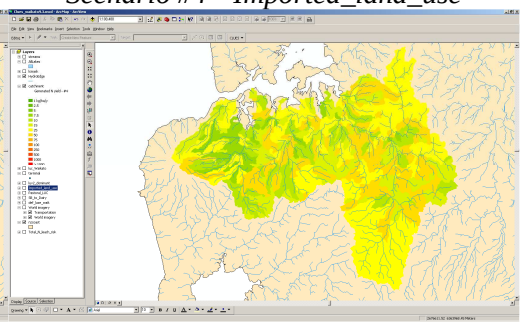
Scenario #2—SB_to_dairy



Scenario #3—Pastoral_LUC



Scenario #4—Imported_land_use

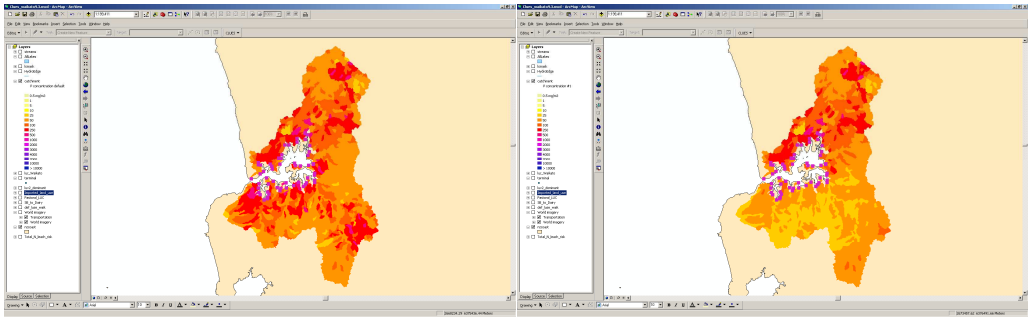


6.4.2 Bar Charts

Bar charts were discussed in Section 5.2 for the case where no land-use change scenarios have been simulated. Bar charts created after simulating a land-use change scenario will display both the results for the particular scenario run as well as the default values (*Scenario #0*). NOTE that the same river reaches must be selected for each CLUES 2.0.6 run to enable bar chart comparisons. Bar charts are displayed using the same general method as in Section 5.2.

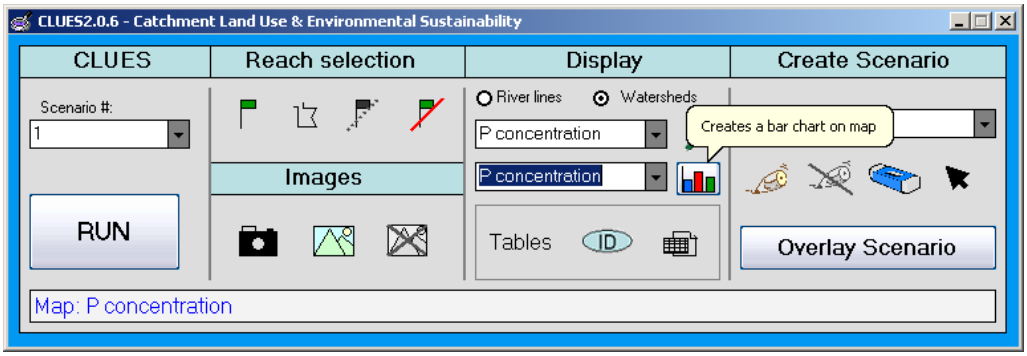
In this example, total phosphorus concentrations for the streams flowing into Raglan Harbour are summarised for the default land use and the interactive sketch scenario (*Scenario #1*). Both scenarios have been run for the same selection of river reaches. Note that since *Scenario #1* only effects land use to the south of the harbour, the results are the same as the default for the northern river reaches. The P concentration watershed maps are given below, the *HydroEdge* layer has been switched off to aid display.

Default *Scenario #1*

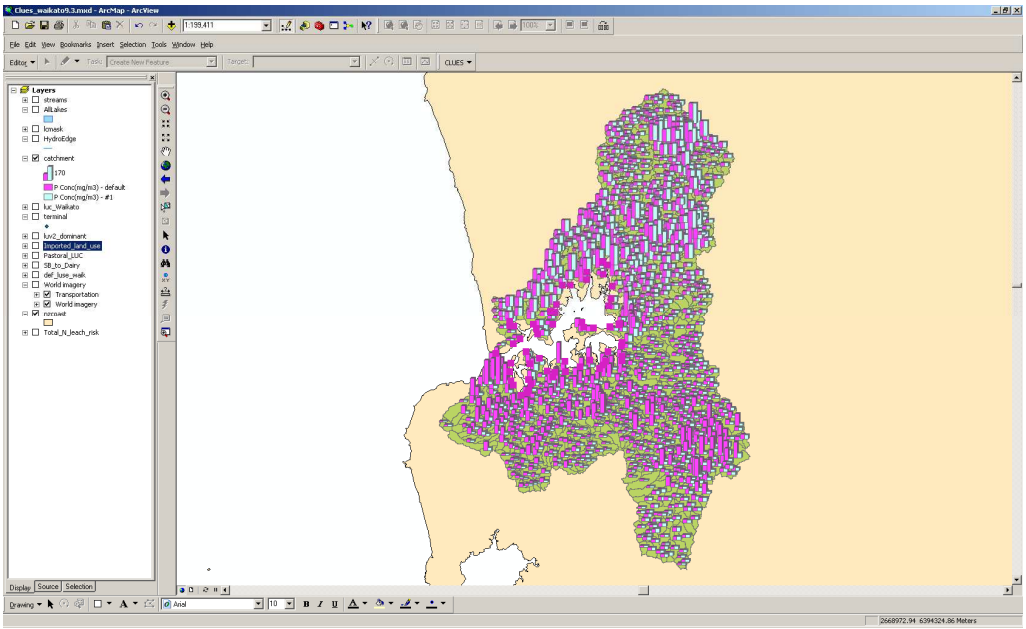


It is clear that the land use change to the south has resulted in changed phosphorus concentrations—however, the difference can be hard to determine. The bar chart allows users to quickly assess the degree of change across the selected area without having to toggle between maps.

1. Select the scenario to be compared and the result to be displayed from the respective drop-down menus. Click on the *Chart* icon.

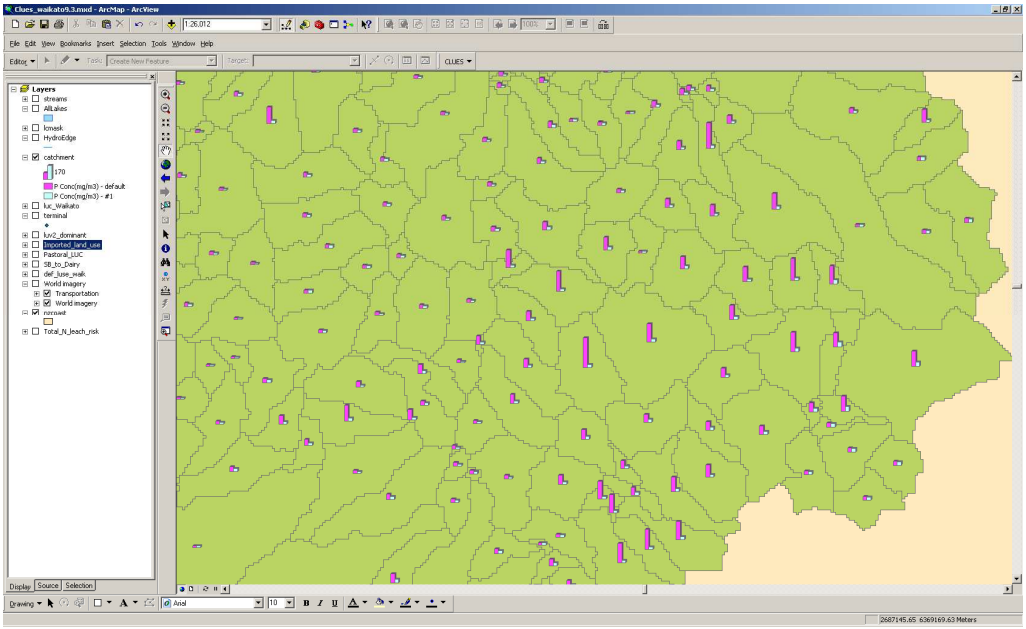


A bar chart with columns for both the default land use and the selected land-use change scenario will be mapped. The legend will appear under the *catchment* layer in the *TOC.*



In this example, the concentrations from the northern catchments are unchanged (no land use change in *Scenario* #1) but decreased to the south.

TIP: zooming in can help interpretation for sections of large catchments.

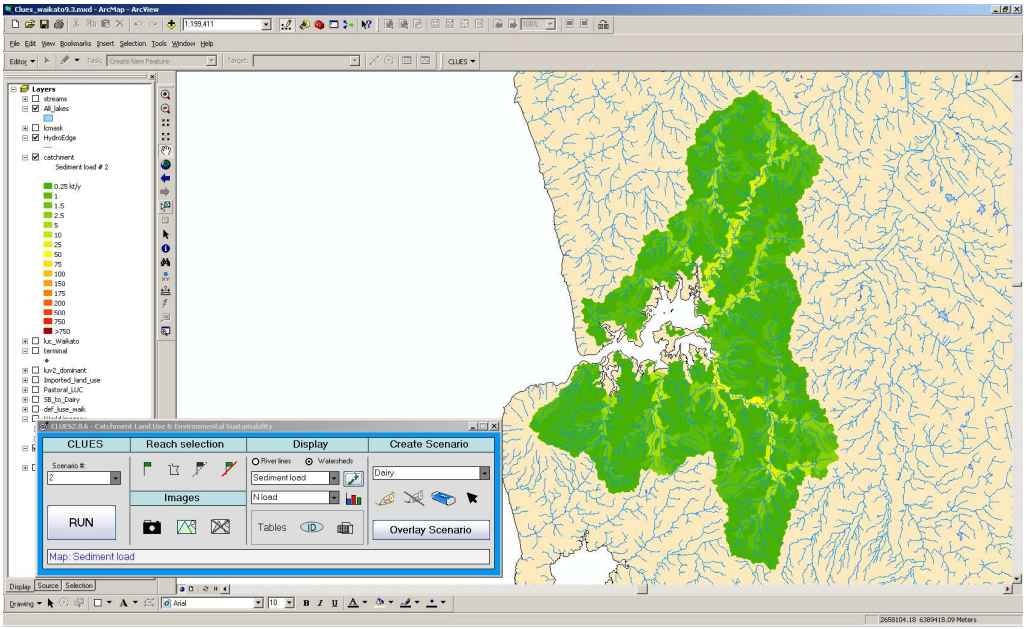


6.4.3 Imaging tools

The results generated by CLUES 2.0.6 for a particular river reach selection and land use scenario are updated after every model run. This means that CLUES 2.0.6 cannot toggle between the results for different river reach selections modelled with the same land use scenario. The CLUES 2.0.6 Image tools allow result maps or charts of different catchment selections to be compared by creating a geo-referenced Tagged Image Format file (.tiff) of the display screen. These images can be used to display earlier model runs. The image file is saved for display within ArcGIS or for use in a document. Geo-referencing means that images can be panned or zoomed within ArcGIS for the extent covered in the image.

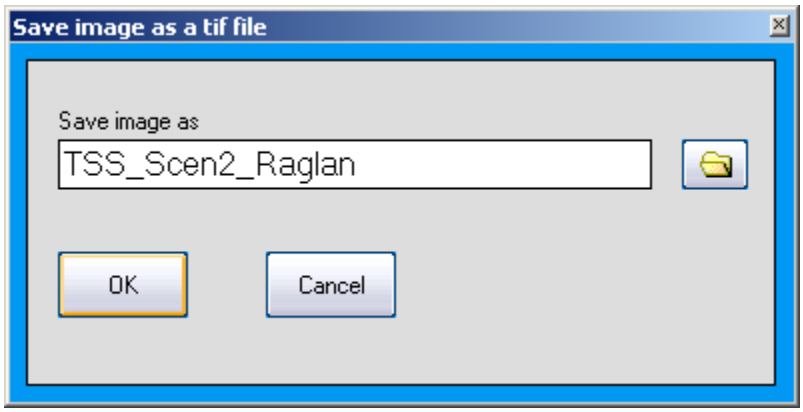
In this example, TIFFs will be created for the sediment load map for streams flowing into Raglan Harbour using the sheep and beef to dairying scenario (i.e., *Scenario #2, SB_to_dairy*). CLUES will then be re-run for Kawhia Harbour to the south using the same scenario. The images created for each catchment selection will then be displayed.

1. Run CLUES for the selected river reaches and scenario and display the map or chart to be saved with CLUES *Images*. Note that the imaging tool will take a screen print of the display including ArcGIS highlighting, so make sure that you have the display as you want it to appear in the tiff.



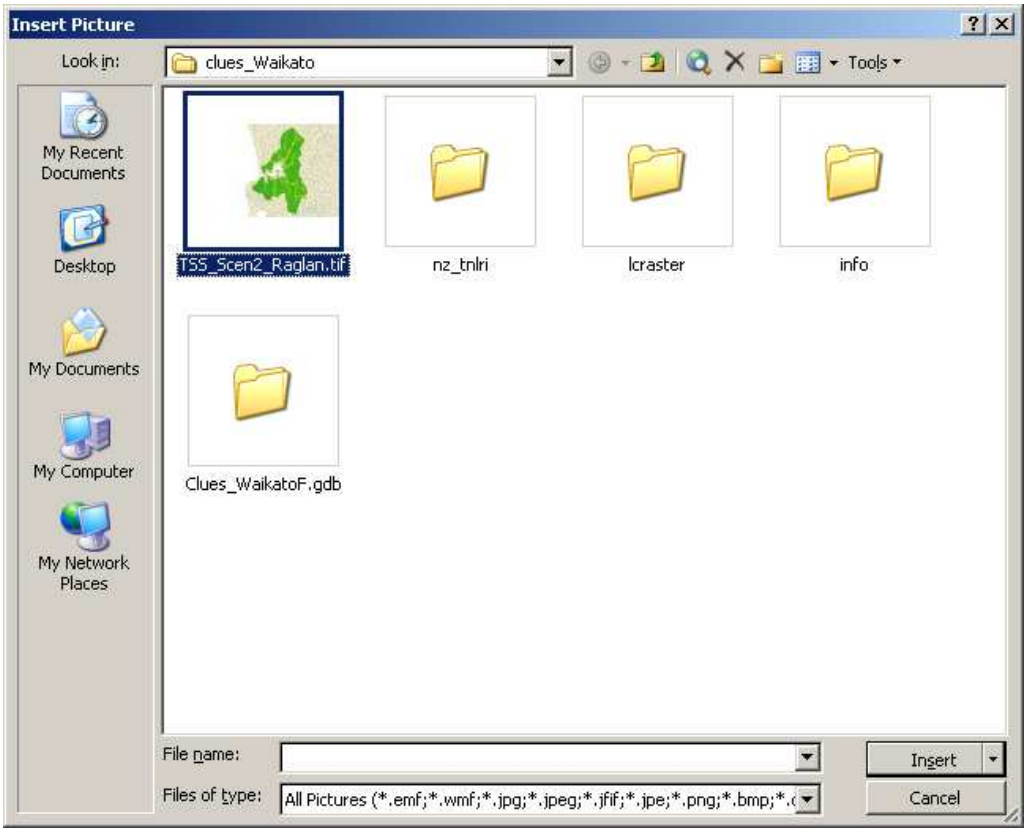
2. Click the *Camera* icon under *Image* tools.

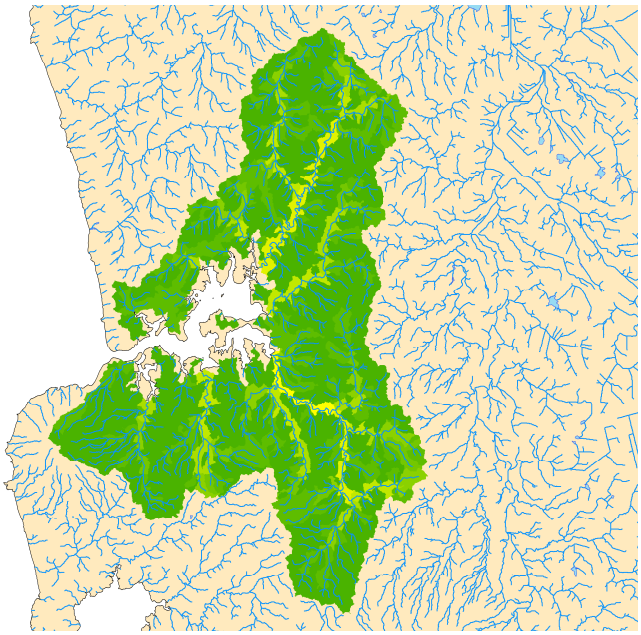
Give the file a suitable name in the *Save image as* box and click *OK*.



The default file location is the CLUES 2.0.6 directory, to choose another location, click the *Folder* icon to browse and save accordingly.

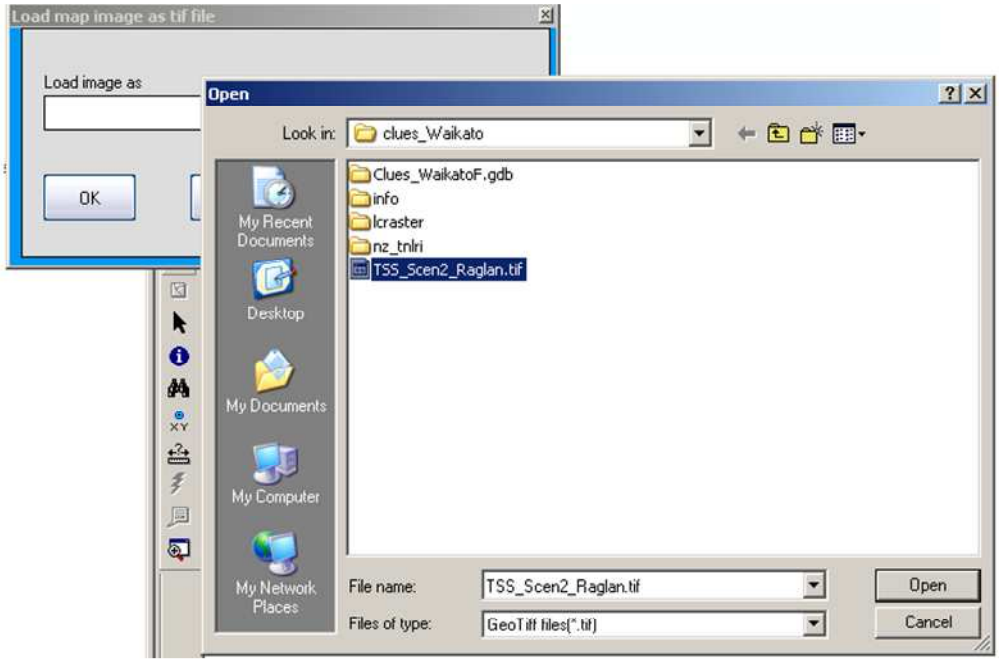
3. The image will be saved into the directory and can be imported into other documents (this manual was prepared using MS Word, pictures are inserted using the *Picture From File* command under the *Insert* menu).

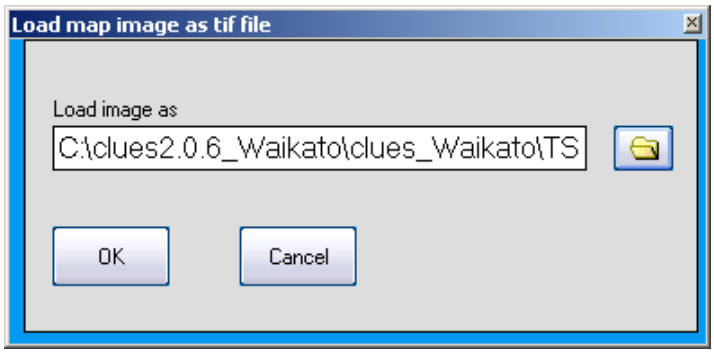




4. To view the tiff as a geo-referenced image within ArcGIS, click the *Retrieve image* icon.

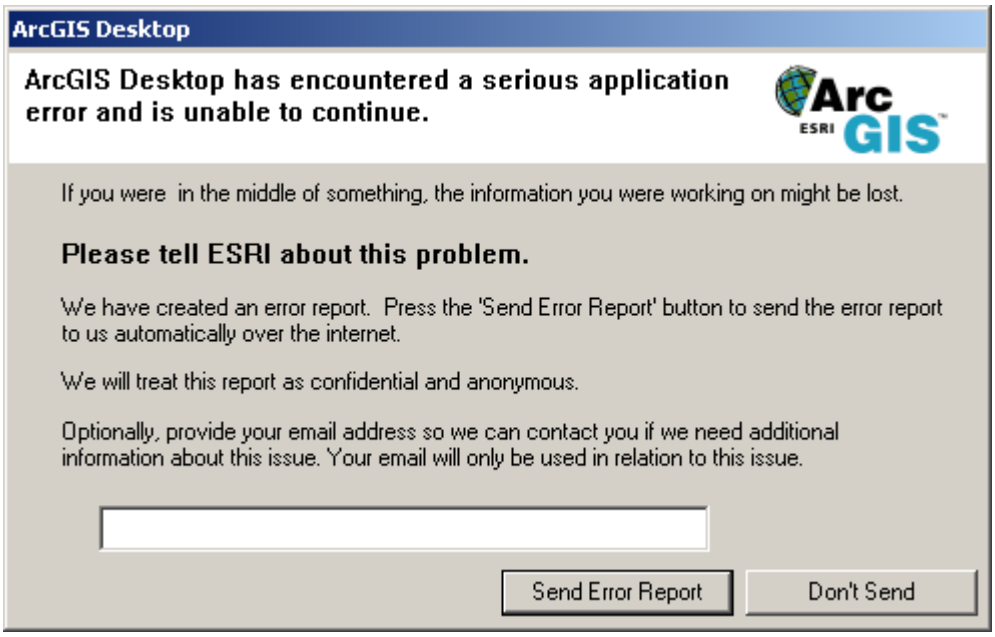
In the *Load map image* dialogue box, either provide the file name and directory pathway or browse by clicking the *Folder* icon to locate the tiff and then click *OK*. Take care to use the correct directory pathway and file name.





Note: the Add data tool on the Standard ArcGIS toolbar can also be used to add the tiff file to the map document.

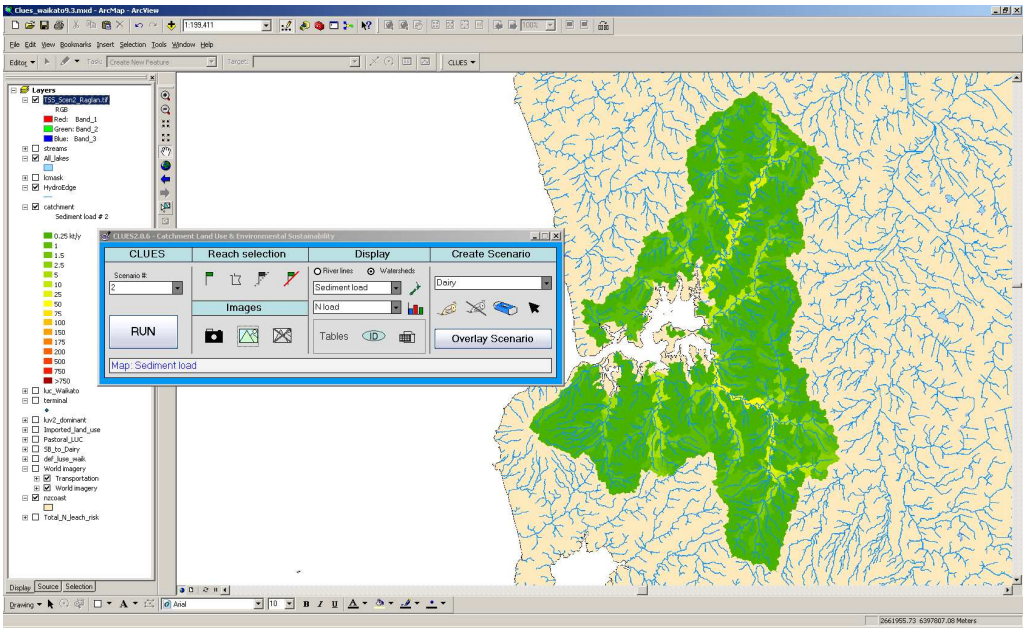
TROUBLE SHOOTING: ArcGIS crashed when I tried to retrieve my image.



TROUBLE SHOOTING: I get this error message when I tried to retrieve my image.

In both cases, CLUES 2.0.6 was unable to find the image. ArcGIS crashes when there is no specified directory pathway. The lower error occurs when the name is incorrect. Take care to use the correct directory pathway and image name. If in doubt, browse to locate the image by clicking the *Folder* icon when you retrieve an image.

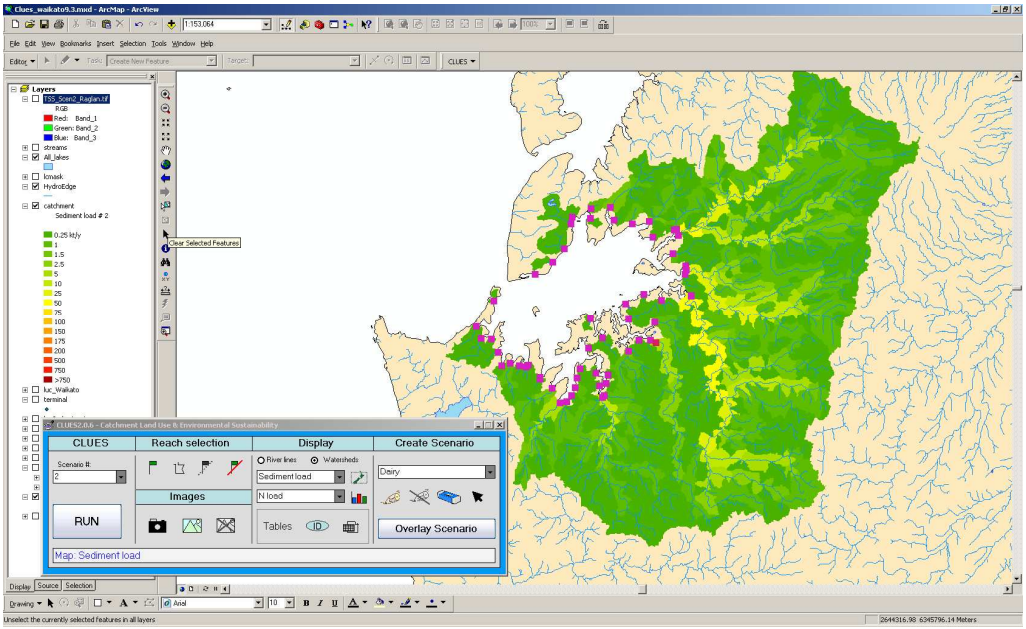
5. The tiff file will appear in the *TOC* under the *Display* tab as the last layer in the layer hierarchy tree. To view the image in the display window either uncheck all the overlying active layers or move the image up the *TOC*.



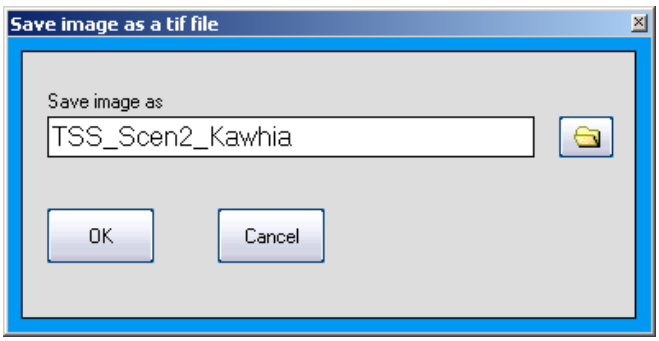
NOTE: there will be some loss of resolution compared to the original display.

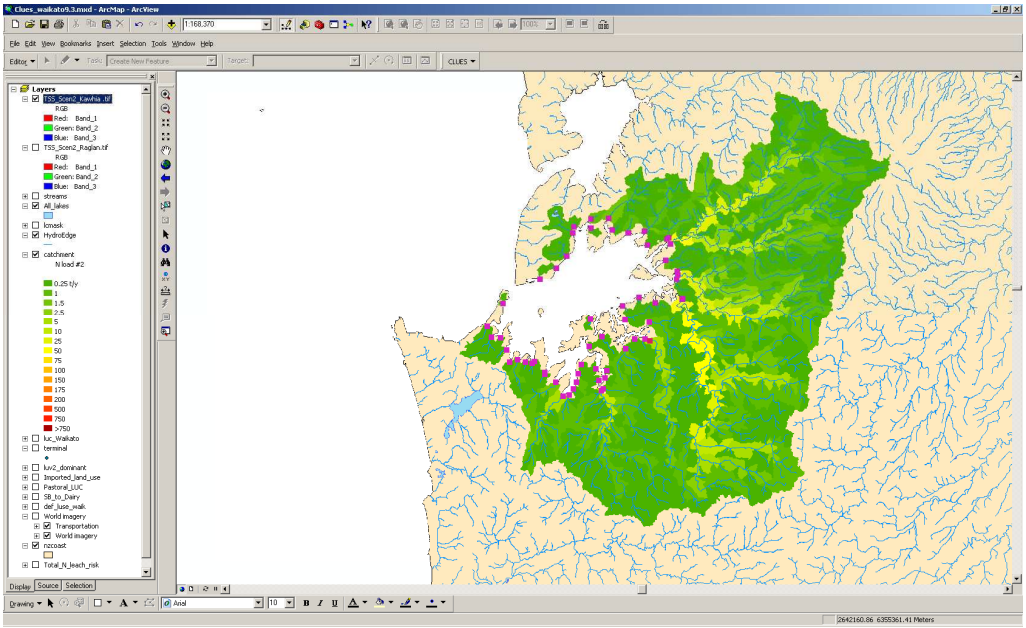
6. Turn off the tiff image in the *TOC*.

7. Make a new river reach selection and re-run CLUES. In this example, river reaches draining to Kawhia Harbour have been selected and simulated using *Scenario* #2, sediment load is displayed.

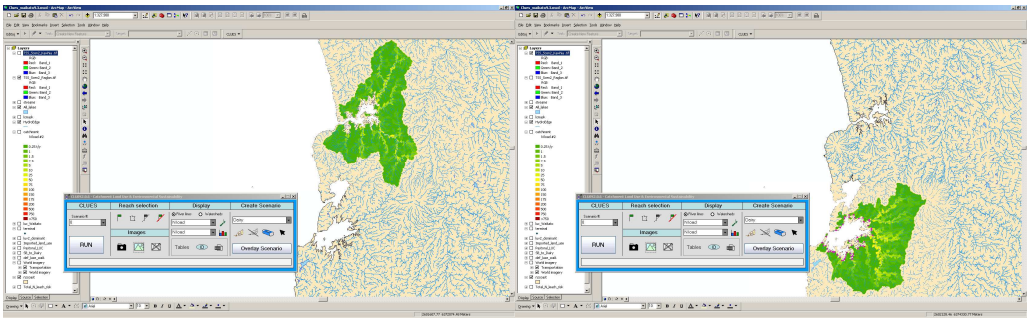


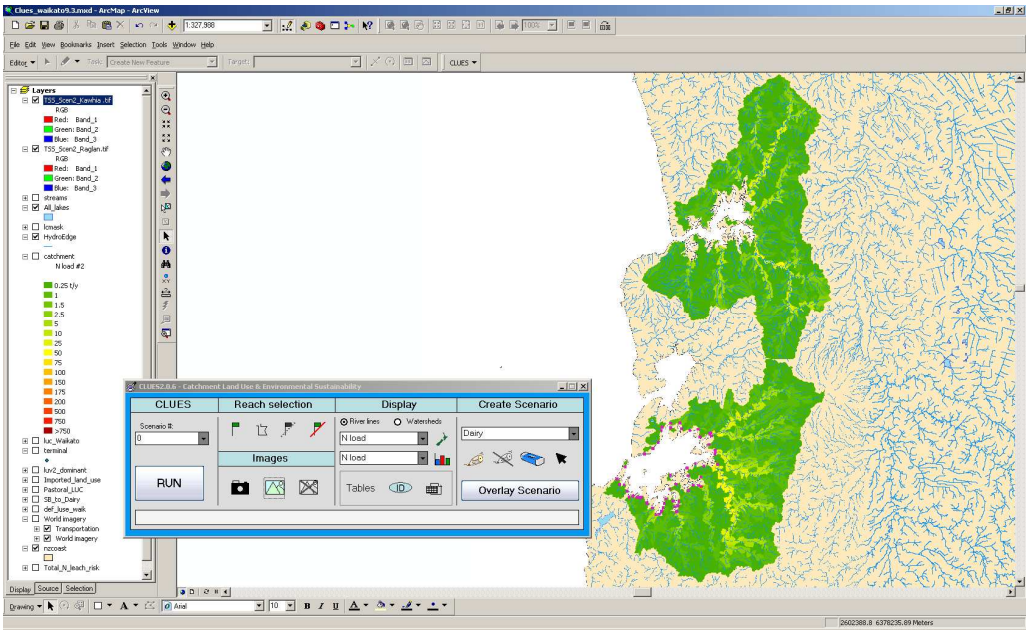
8. Using the same method above, make a geo-referenced tiff file of the new simulation and add it to the map document.





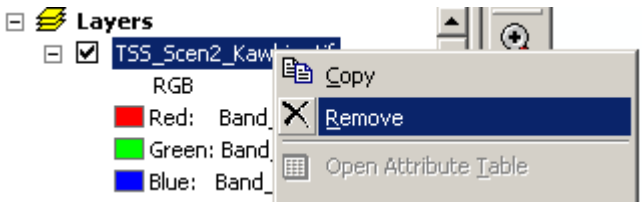
9. The images can be toggled or displayed together by selecting or deselecting them in the *TOC*.





Note, in this case the two images overlap slightly in their spatial extent so that the layer uppermost in the *TOC* covers that below.

10. To remove a tiff image from the *TOC*, right click on the layer and click on the Remove command.

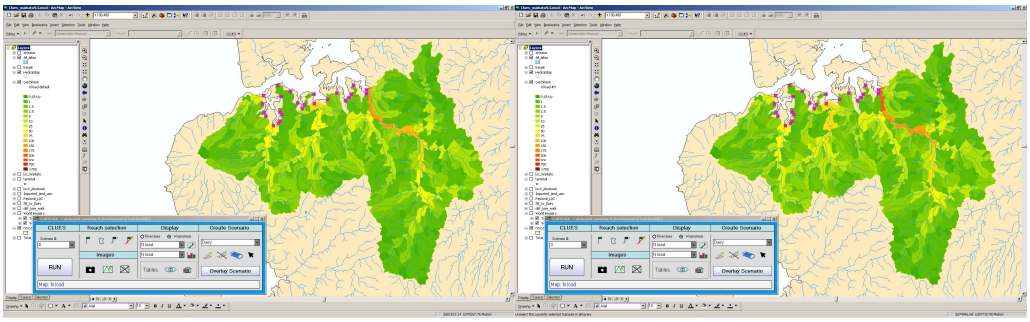


6.4.4 Tables

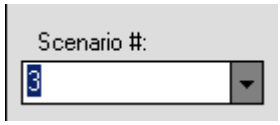
Once a land-use scenario has been simulated by CLUES 2.0.6, the tables discussed in Section 5.3 are updated to include the summary results for the scenario along with the results for the default land use scenario. This is similar to toggling between map and chart displays, except that the results for the latest model run for each scenario are summarised within the respective CLUES table. In this example, the results for the default land use and *Scenario* #3 (*Pasture_LUC*) are simulated for the catchments to the south of Raglan Harbour.

1. Select the river reaches to be modelled and run CLUES 2.0.6 both for the default land use scenario (*Scenario* #0) and the desired land use change scenario (here *Scenario* #3).

N load: Default (*Scenario* #0) N load: Pasture_LUC (*Scenario* #3)

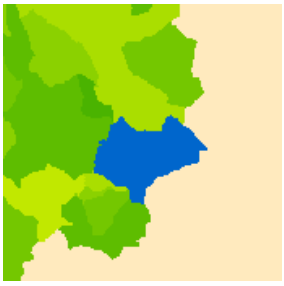


2. To investigate individual sub-catchments, make sure the land use change scenario is selected and then click the *Identify sub-catchment* icon under the *Display* tools (see Section 5.3.1).



Click on the sub-catchment to be investigated. The sub-catchment with flash once to show its location. The sub-catchment summary table will open displaying results for that sub-catchment for both the default land use and the selected land use change scenario. Clicking on other sub-catchments will update the table.

N /P Loads, Triple Bottom Output	
AREA_HA	170.730
CFS($) - #3	8086.120
CFS($) - default	8309.710
FTE - #3	0.088
FTE - default	0.091
GDP($) - #3	8805.610
GDP($) - default	9049.100
N Conc(mg/m3) - #3	635.061
N Conc(mg/m3) - default	638.025
N cum.yield(kg/ha/y)-#3	14.449
N cum.yield(kg/ha/y)-default	14.516
N gen.yield(kg/ha/y)-#3	16.316
N gen.yield(kg/ha/y)-default	16.392
N load(t/y) - #3	2.467
N load(t/y) - default	2.478
P Conc(mg/m3) - #3	193.345
P Conc(mg/m3) - default	193.820
P cum.yield(kg/ha/y)-#3	4.768
P cum.yield(kg/ha/y)-default	4.779
P gen.yield(kg/ha/y)-#3	5.030
P gen.yield(kg/ha/y)-default	5.040
P load(t/y) - #3	0.814
P load(t/y) - default	0.816
peta E.coli per year-#3	0.053
peta E.coli per year-default	0.053
SED gen.yield(kg/ha/y)-#3	12.462
SED gen.yield(kg/ha/y)-default	12.420
SED load(kt/y) - #3	2.128
SED load(kt/y) - default	2.121



TROUBLE SHOOTING: When I click on a catchment to create a table, I get values of -0.10 for all the results of either the default or the land use change scenario.

This means that CLUES has not been run for the sub-catchment selected for one of the scenarios and CLUES is returning the default value given in the *catchment* layer for un-simulated sub-catchments.

N /P Loads, Triple Bottom Output	
AREA_HA	170.730
CFS($) - #3	8086.120
CFS($) - default	-0.100
FTE - #3	0.088
FTE - default	-0.100

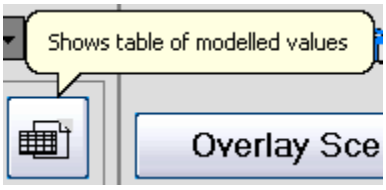
CLUES has not been run using the default land use (*Scenario #*0) for the selected sub-catchment.

N /P Loads, Triple Bottom Output	
AREA_HA	170.730
CFS($) - #3	-0.100
CFS($) - default	8309.710
FTE - #3	-0.100
FTE - default	0.091

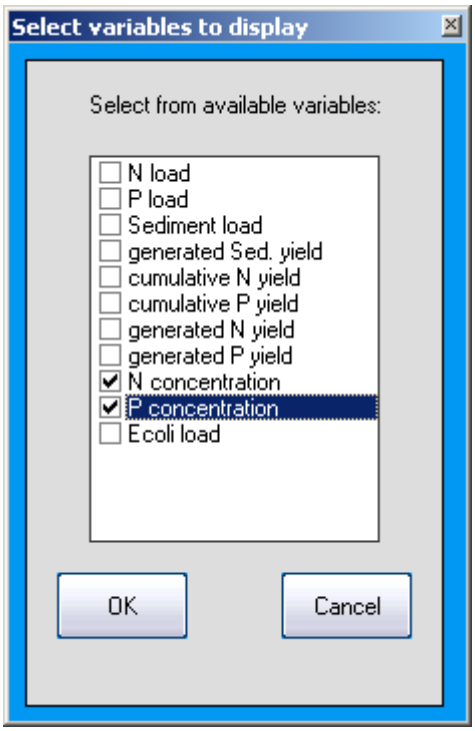
CLUES has not been run using the changed land use scenario (here *Scenario* #3) for the selected sub-catchment.

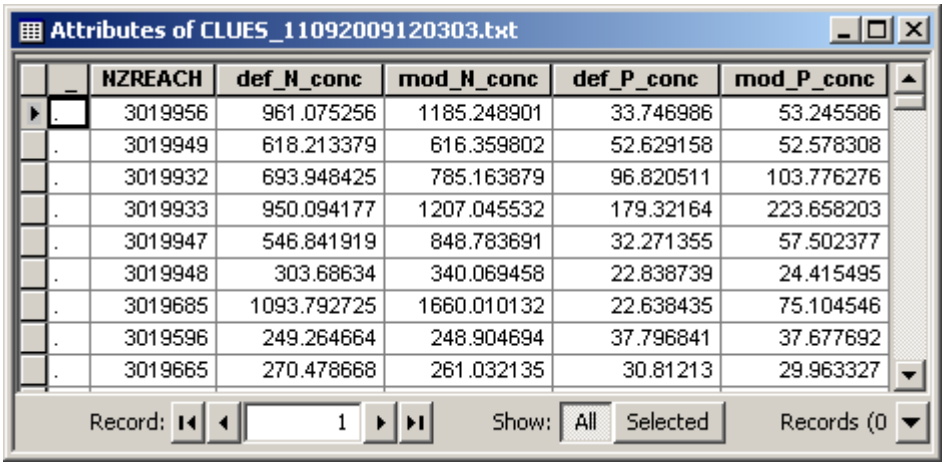
Make sure that you have run CLUES for the same river reach selection before you use the *Identify sub-catchment* tool.

3. To display the model summary for all the river reach sub-catchments modelled, click the *Modelled area summary* icon under the *Display* tools (see Section 5.3.2).



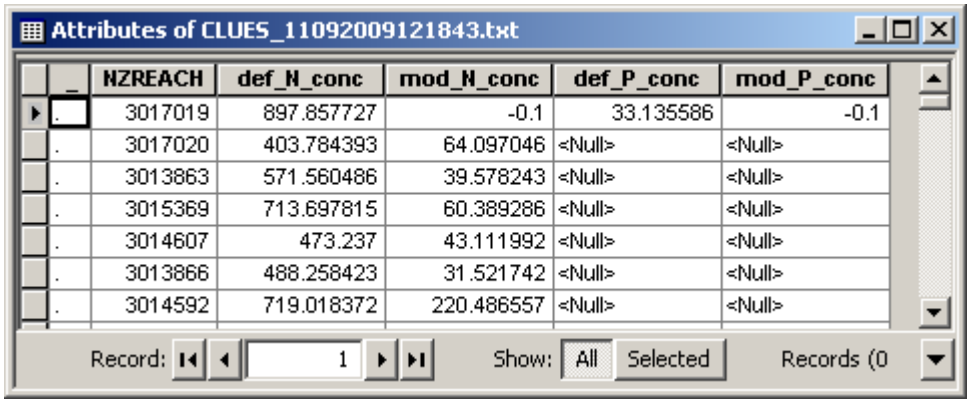
4. Select the variables to be included in the table, here nutrient concentrations are compared. Click *OK*.





The table is formatted as an ArcGIS data table where each sub-catchment is identified by river reach (NZREACH). See Section 5.3.2 for information on how to store and retrieve the table.

TROUBLE SHOOTING: When I try to make a summary table for a land use change scenario, my table is not complete and I get error values for the land use change.



This means that the default scenario has not been simulated for the selected river reaches.

Make sure that you run CLUES for the same river reach selection before displaying the results with a table.

7. Advanced CLUES use and display

The results presented above have been displayed using the default CLUES 2.0.6 settings. ArcGIS tools and adding other layers to the map document can be used alongside CLUES to customise display, aid interpretation of results, construct scenarios, extract data for post-processing or analysis.

7.1 Saving and exporting results

CLUES 2.0.6 saves the most recent results for each scenario simulated in the *catchment* layer, along with information about stream network (e.g., NZREACH gives the NZ reach number which identifies the reach in the REC database) and land use proportions. There are 84 result fields held in the *catchment* layer, these are listed in Appendix Two along with their aliases and descriptions. The *catchment* layer is joined to the *streams* layer for display of river line maps. The result fields are undated following each model run. To save results for later analysis or display, thus allowing CLUES to be run for other catchment selections or more than five land use change scenarios, you can export the data into a new file.

The easiest method of exporting data is to open the simulation summary tables generated using CLUES (see Sections 5.3.2 and 6.4.4), which are saved as CSV text files. Each table contains the results for the default and, if a scenario has been selected, the results for that scenario. By copying and pasting the results from several simulations with the same catchment selection, you can compare scenarios (e.g. plots, statistics) or create new fields (e.g., ranks, differences). By saving the analysis under a new name as a text file, it can be added back into ArcGIS. As the tables also include the NZ reach number for each river reach simulated, you can use the join or union tools (on NZREACH) with layers such as *HydroEdge* to display the analysis results.

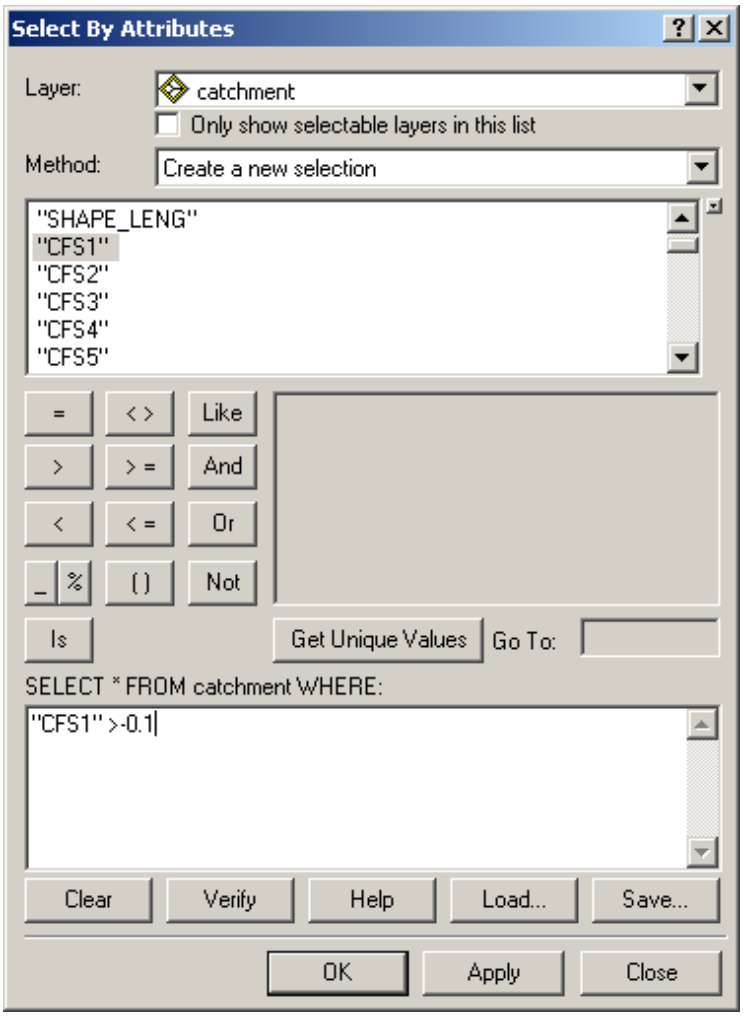
Alternatively, the results held for several land use scenarios can be exported together from the *catchment* or *streams* layers directly. The data can be exported either to a new layer for manipulation within ArcGIS (e.g., changes to symbology, addition of new fields based on analyse of the results such as ranks) or in a form accessible to another package such as a spreadsheet. In both cases, the ArcGIS selection tools can be used to reduce the amount of data exported to only those river reaches that have been simulated. This can reduce the export time significantly.

7.1.1 Exporting to a new layer

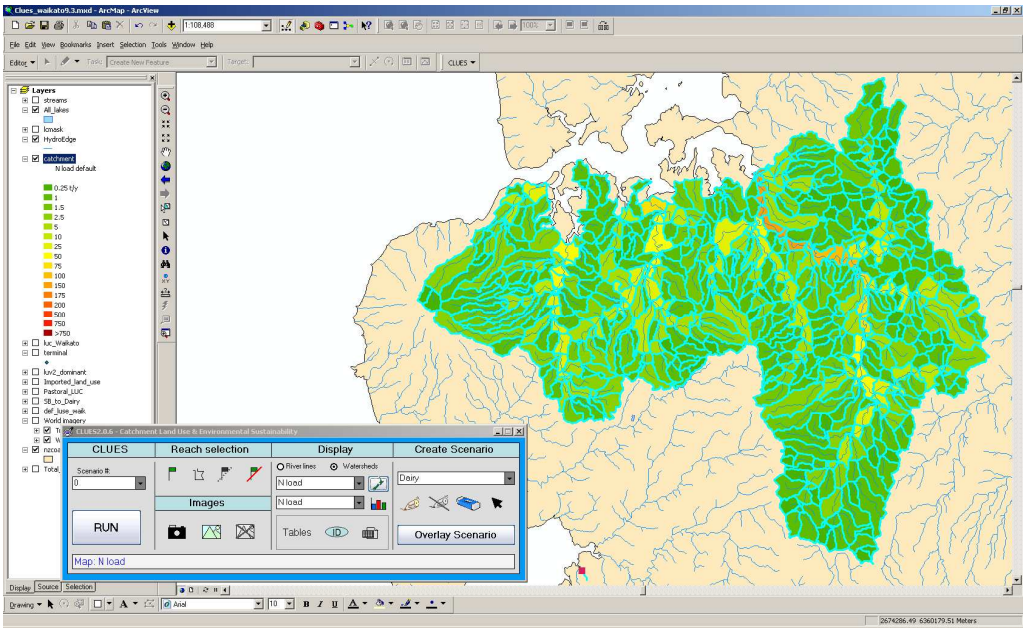
The preparation of the manual has resulted in simulations for the sub-catchments to the south of Raglan with the default and four changed land use scenarios. In this example, these results will be exported to a new layer. The sub-catchments simulated have been selected from the *catchment* layer and their results (sub-catchments that have not been simulated are assigned default values of -0.1) exported to a new layer called *RaglanS_results.shp.* The same technique is used to export results for stream channels (i.e., Riverlines).

1. Run CLUES for the selected sub-catchments using all the required land use scenarios.

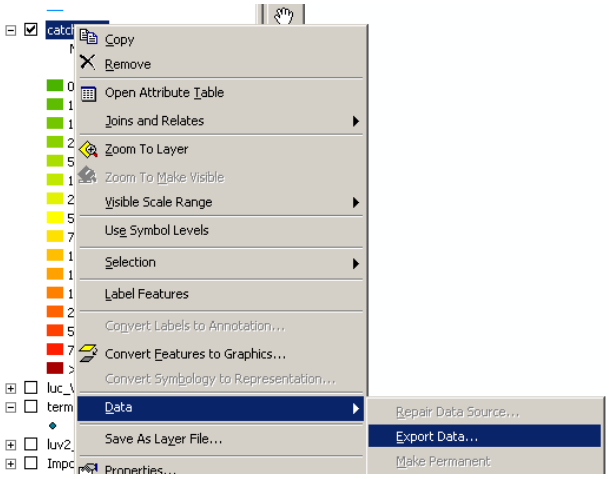
2. Use the ArcGIS *Select by Attributes* tool to select the simulated catchments from the result layer (i.e., those with model results greater than -0.1, here the first result field in the attribute table is used, CFS1—Cash flow surplus for *Scenario* #1, is used for the selection)

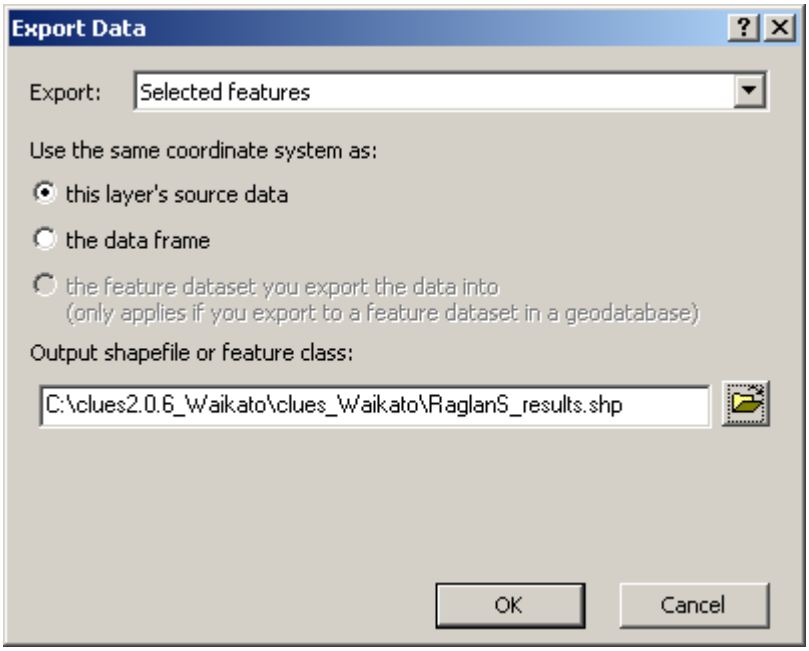


The polygons selected from the catchment layer will be highlighted.

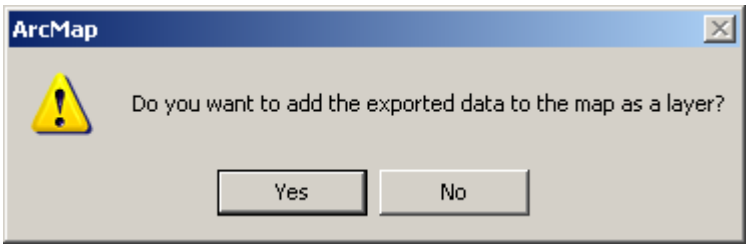


3. Right click on the result layer (here *catchments)* and select *Export Data* from the *Data* menu. Make sure the *Selected Features* appears in the *Export* option box. Save the results under a suitable name (here *RaglanS_results.shp*)

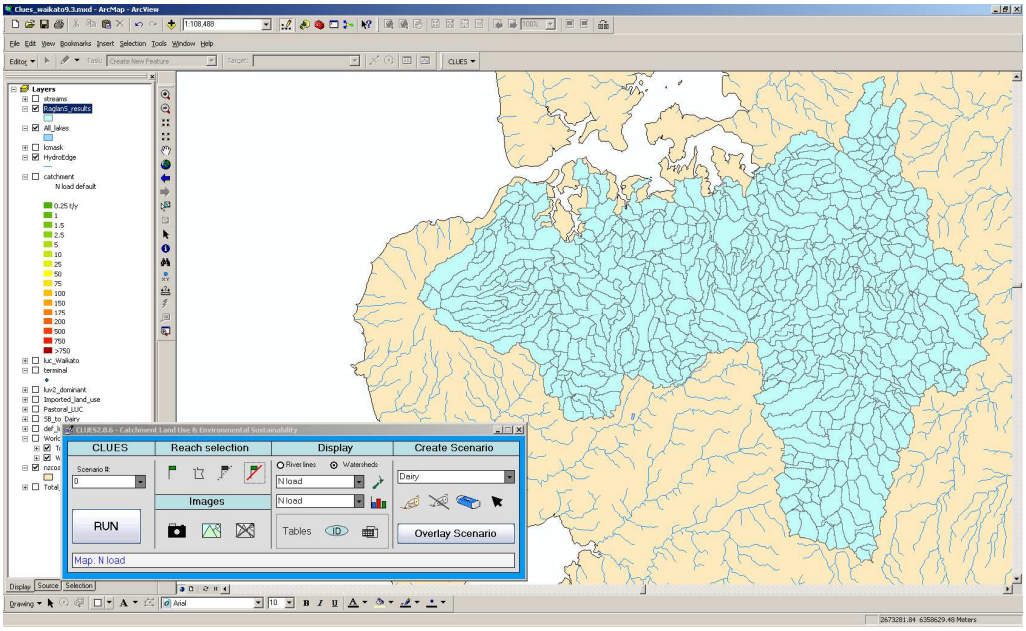




ArcGIS will inform you of the export progress, when complete, click *Yes* to add the layer to the map document.



Clear the selection and turn off the result layer in the *TOC.* The simulations results are now available for further analysis or display.



Note that while there are result fields for all the scenarios (0–5), the values for those scenarios not simulated will have the default -0.1 in the attribute table. In this example *Scenario* #5 which has not been used.

Attributes of Raglan5_results

NLOSS5	GDP1	GDP2	GDP3	GDP4	GDP5	FTE1	FTE2	FTE3	FTE4	FTE5	CFS0	NLC
-0.1	0	68059.898	75700.297	23619.5	-0.1	0	0.81	0.901	0.283	-0.1	26310.6	70
-0.1	0	43072.102	6952.99	17037	-0.1	0	0.509	0.07	0.204	-0.1	5756.92	12
-0.1	0	9583.88	15580.9	4425.2	-0.1	0	0.114	0.186	0.053	-0.1	1088.12	3
-0.1	0	94400.602	95309.898	135680	-0.1	0	1.126	1.137	2.656	-0.1	31832.1	85
-0.1	0	25686.699	33210	15322.3	-0.1	0	0.307	0.397	0.184	-0.1	2786.84	7
-0.1	0	127347	53197.898	425332	-0.1	0	1.518	0.625	7.723	-0.1	19074.9	52
-0.1	0	135158	222427	56200	-0.1	0	1.612	2.661	0.673	-0.1	28121.301	76
-0.1	0	24515.301	2916.66	131321	-0.1	0	0.293	0.034	2.385	-0.1	1988.28	5

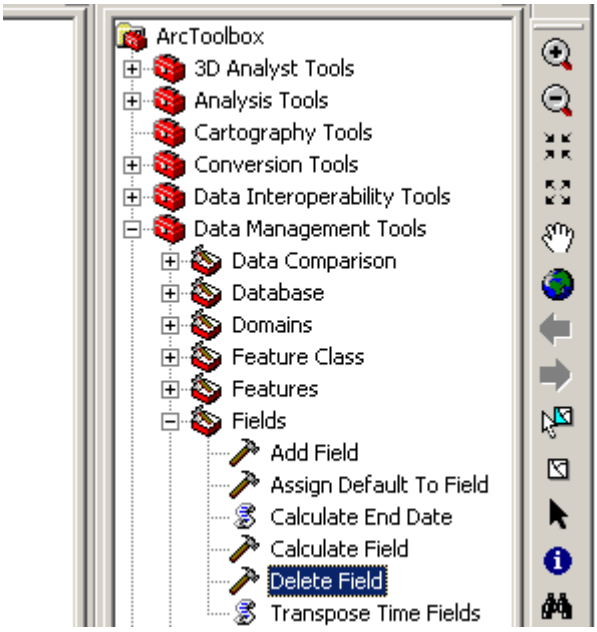
Record: 1 Show: All Selected Records (0 out of 640 Selected) Options

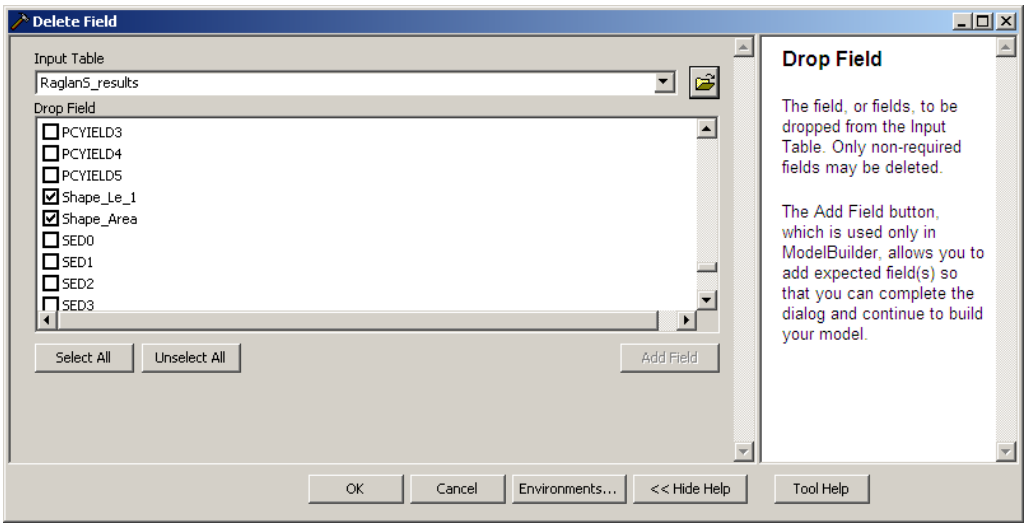
7.1.2 Exporting data to other software packages

Exporting CLUES results allows post-processing, analysis and display of CLUES results in other software packages. The number of fields in the results attribute tables (i.e., the *catchment* and *streams* layers) is too great to be exported as a text file directly (there are over 150 fields). This means that a number of fields will need to be removed before the results can be extracted. It is essential that the results are exported from the *catchment* or *streams layer* first to a new layer following the instructions above. Deleting fields from these layers will cause CLUES to stop functioning. The fields that hold CLUES model results are listed in Appendix One. Do not delete the NZREACH field as this is the river reach identifier from the REC database that can be used to join the text file with either the catchment or streams layers for display after post-processing or analysis.

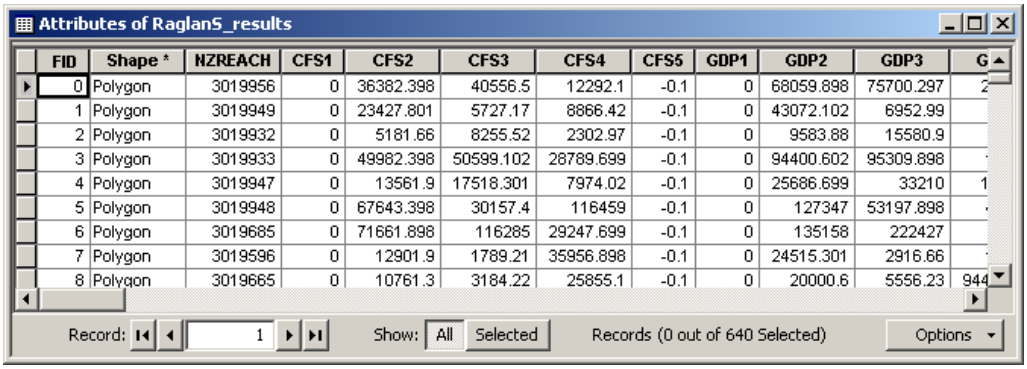
This example will export the data held in the RaglanS_results.shp file created above using two methods.

1. Either delete fields which do not hold results (see above for result fields) data manually in the attribute table (right click on field name and select delete field) or use the ArcGIS delete field tool to delete multiple fields (ArcToolbox\Data Management Tools\Fields\Delete Field). DO NOT delete the NZREARCH field.



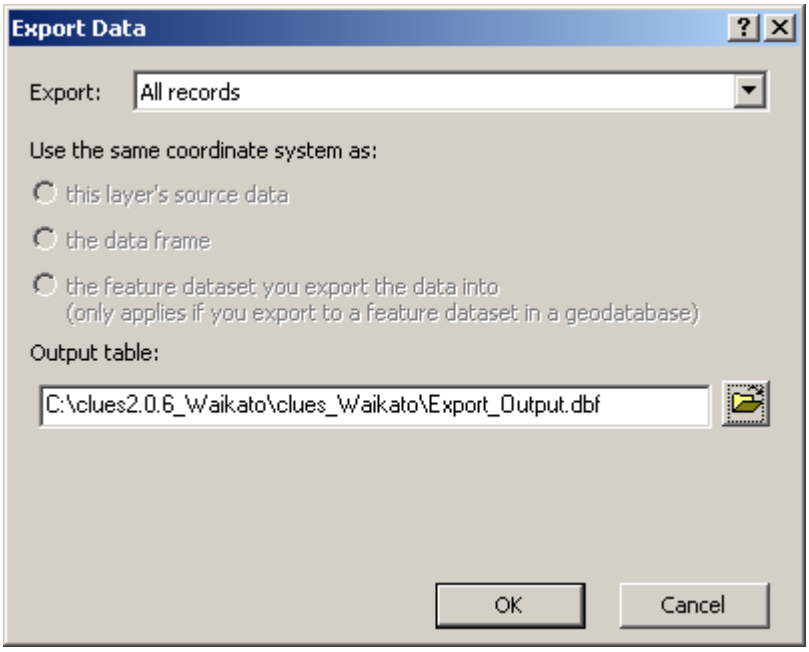


ArcGIS will inform you of the delete process. This step can take some time if a large number of catchments have been simulated.



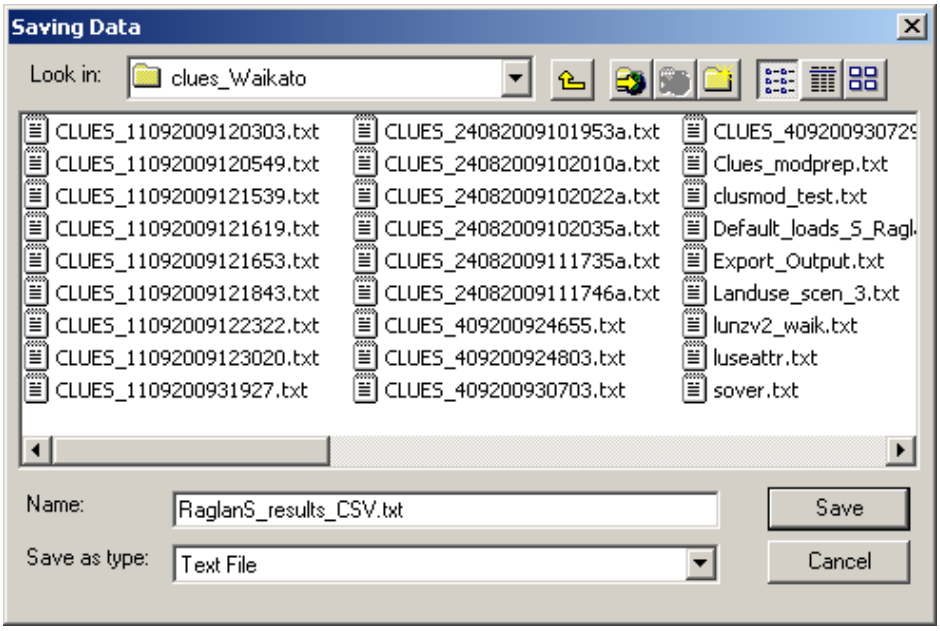
Method One—Export to a text file

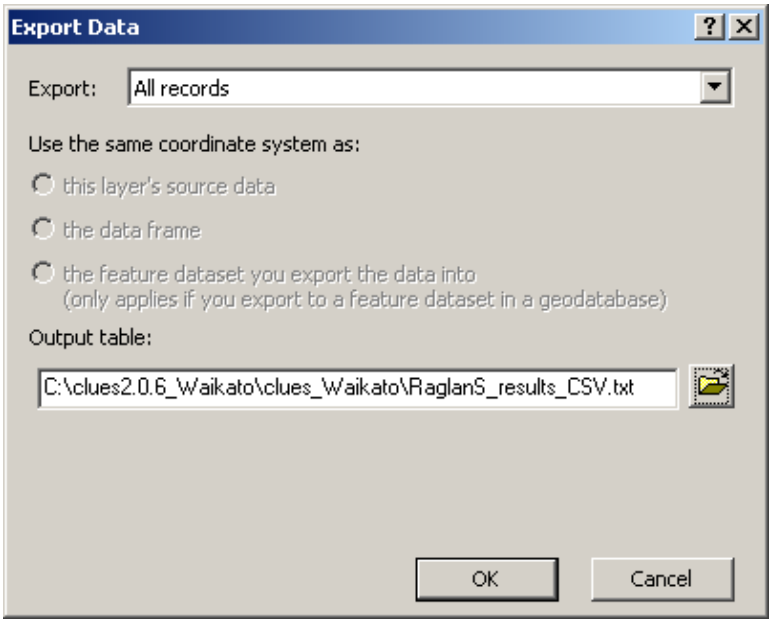
2. In the attribute table, click the O*ptions* button and select Export.



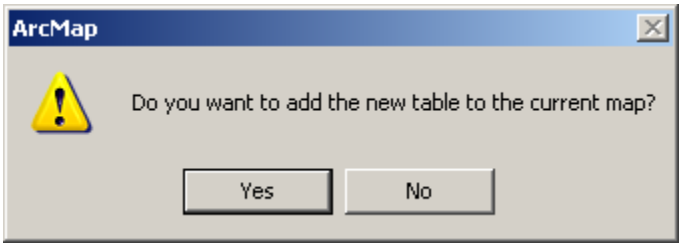
Make sure that *Export* is set to *All records.*

The default *Output table* is formatted as a database file (.dbf) and given the name *Export_Output.dbf*. To change the file name and type, click the *Folder* icon and make the required changes. Click *Save* and then *OK.*

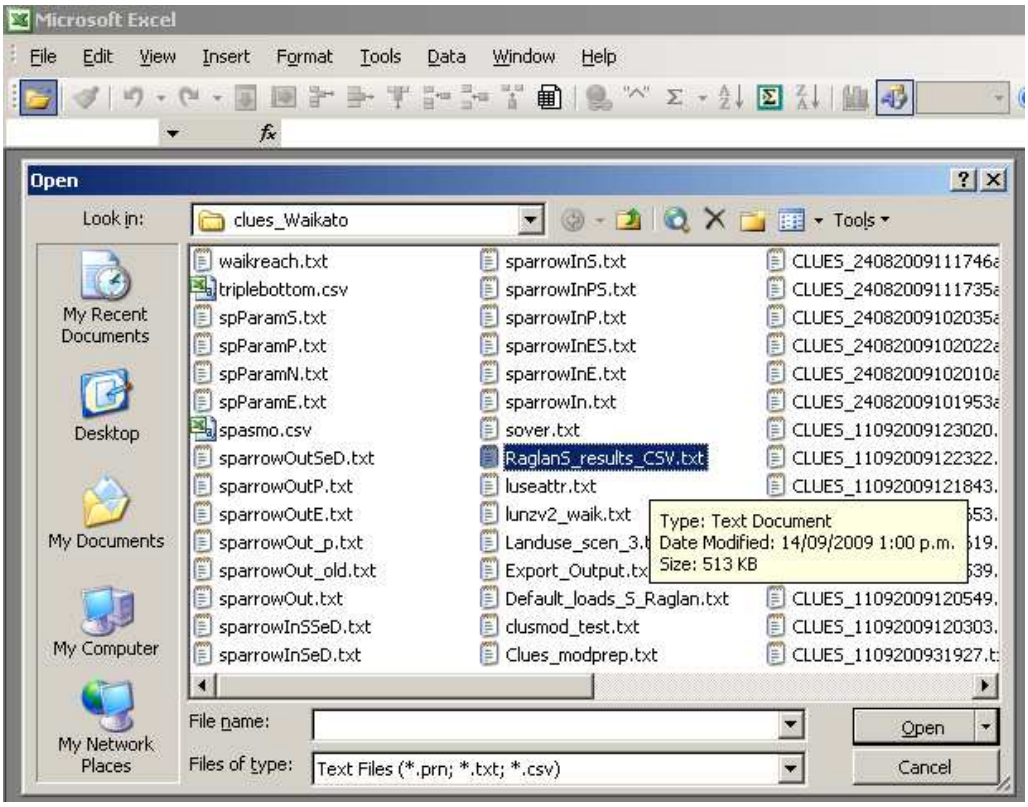




ArcGIS will display the export progress. When the export is complete, ArcGIS will ask whether the table should be included as a layer. Click your choice.



3. The table can now be opened in another package for graphing or calculation.

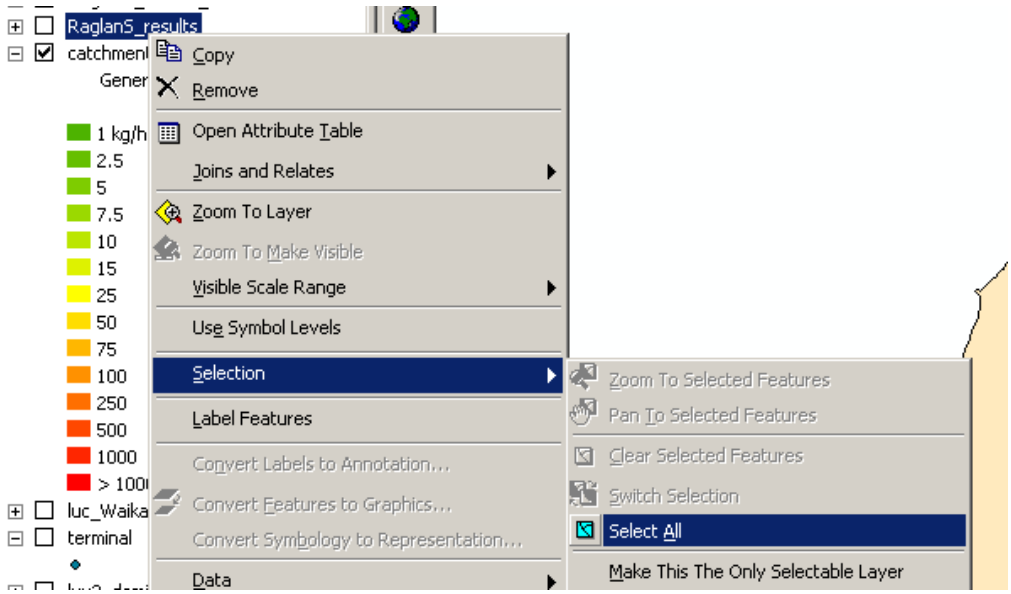


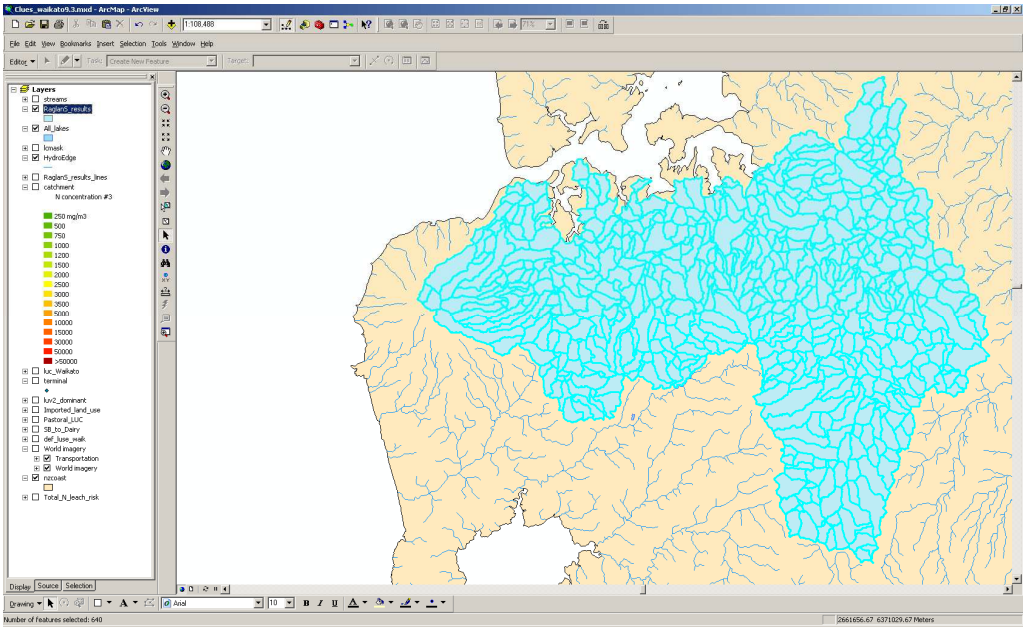
TROUBLE SHOOTING: When I try to export data to a text file, the export stalls and I get an error message like this:

You have too many fields in the layer you are trying to export. Delete the non-result fields taking care NOT to delete the NZREACH field.

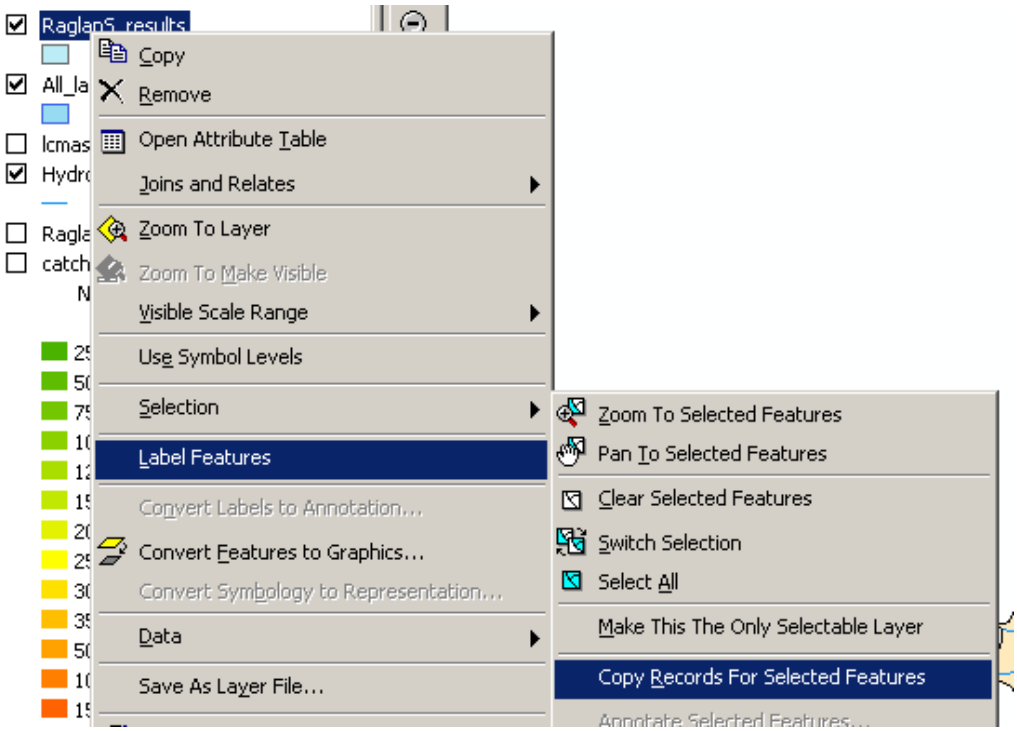
Method Two—Copy to clipboard

2. In the *TOC*, right click on the layer name to select all the rows in the layer under the Selection menu.

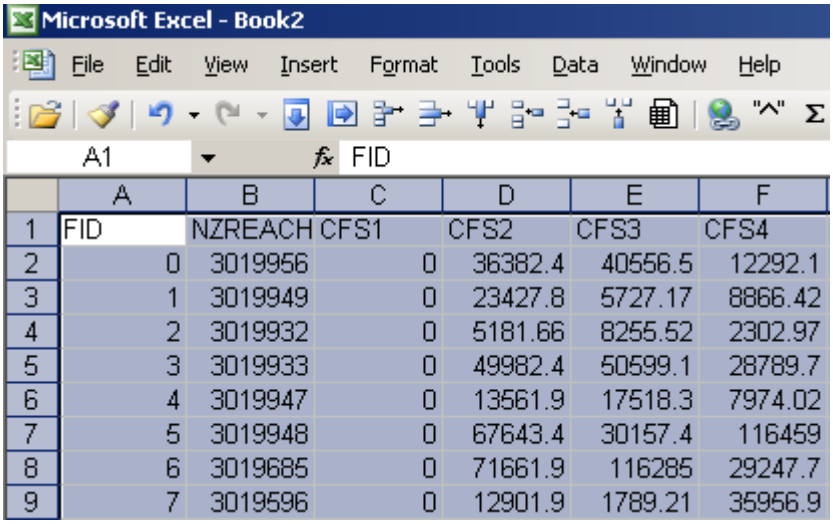




3. Right click again on the layer name and click on *Copy Records for Selected Features* under the *Selection* menu.



4. The data held in the layer attribute table will be copied to the clipboard and can be pasted directly into another software application.



	A	B	C	D	E	F
1	FID	NZREACH	CFS1	CFS2	CFS3	CFS4
2	0	3019956	0	36382.4	40556.5	12292.1
3	1	3019949	0	23427.8	5727.17	8866.42
4	2	3019932	0	5181.66	8255.52	2302.97
5	3	3019933	0	49982.4	50599.1	28789.7
6	4	3019947	0	13561.9	17518.3	7974.02
7	5	3019948	0	67643.4	30157.4	116459
8	6	3019685	0	71661.9	116285	29247.7
9	7	3019596	0	12901.9	1789.21	35956.9

7.2 Symbology

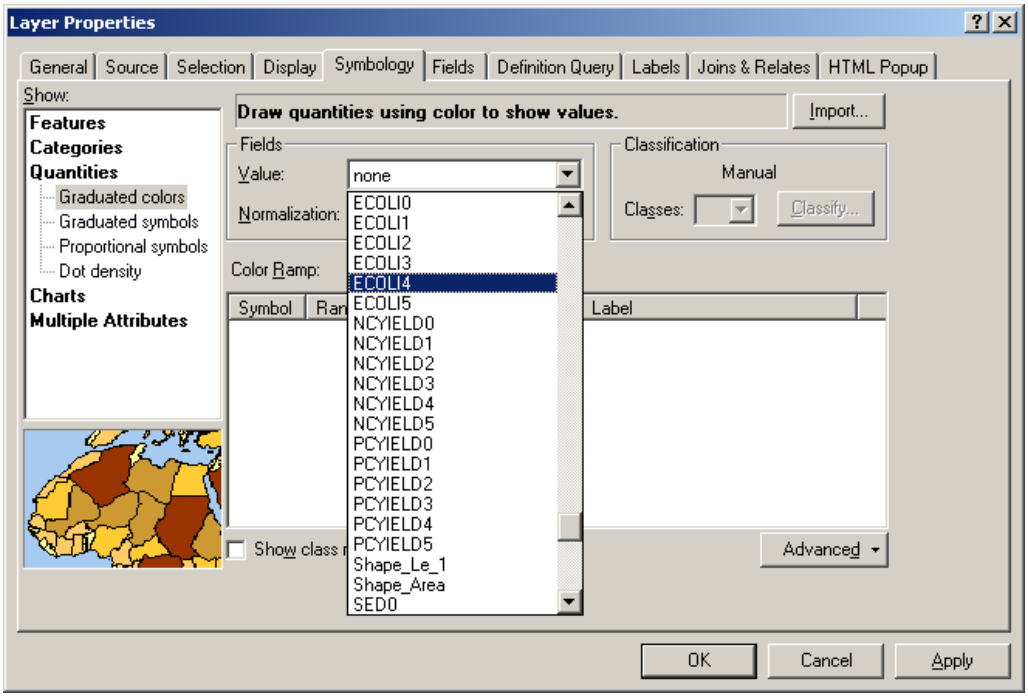
CLUES results are presented using a default display with set symbology and distributions for value intervals. This has the advantage of being able to compare results for different catchments visually but can also mean that in catchment with a narrow range of water quality indictor values it can be difficult to interpret the results.

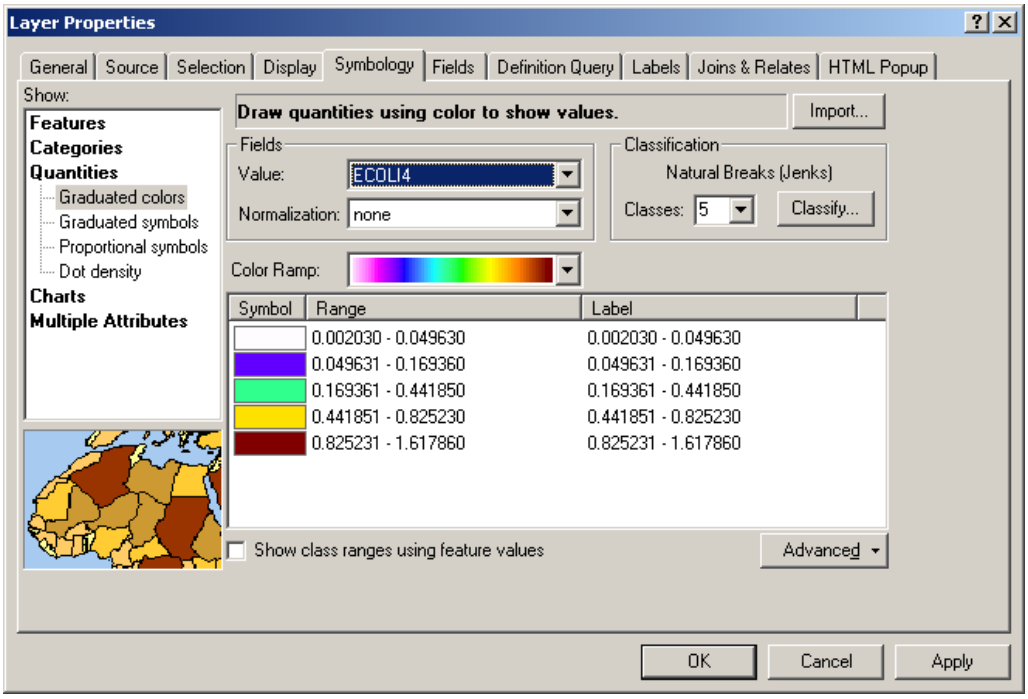
CLUES results are held in the *catchment* layer for watershed maps which is joined to the *streams* layer for river line maps. The default display of CLUES 2.0.6 results can be changed by altering the symbology of these results layers directly. If the default symbology is changed, the map will revert to the default symbology when either the CLUES *map* or *chart* icon is next clicked.

Altering the result layers directly can be problematic as these layers hold data for all the river reaches in the regional database, not only those simulated. The CLUES distributions and symbology have been adjusted in the default display so that river reaches and sub-catchments outside the selected simulation area are not mapped (these are assigned default values or -0.1 for all results fields). This means that any change to the symbology must take these un-simulated reaches into account. Instead, it is recommended that the results for the simulated reaches be exported to a new layer (see the previous section). Doing so means that you can display any result outside CLUES regardless of future CLUES runs.

In this example, the symbology of the exported results layer created in the previous section (*RaglanS_results*) is adjusted so that the *E. coli* load simulated for *Scenario* #4 (Imported_land_use) has a yellow-brown colour ramp and the result range split in to deciles.

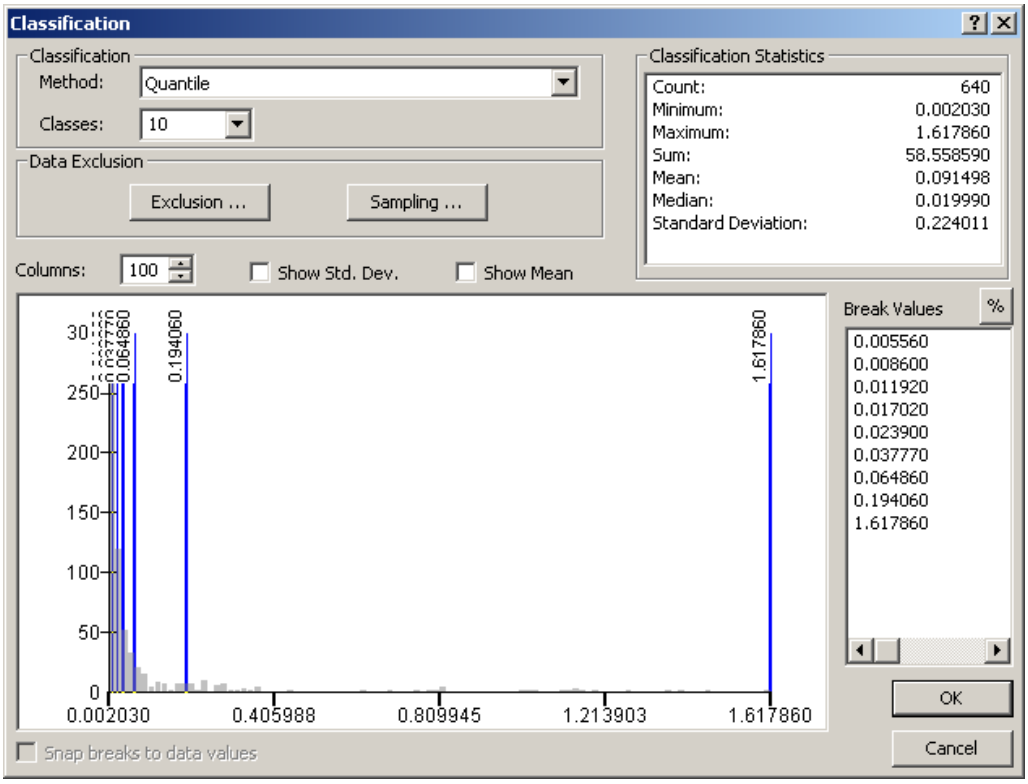
1. Right click on the result layer in the *TOC*, select *Properties* and open the *Symbology* tab. Select Show Quantities / Graduated colours and select the result to be displayed (here ECOLI4) from the Value-drop down menu.



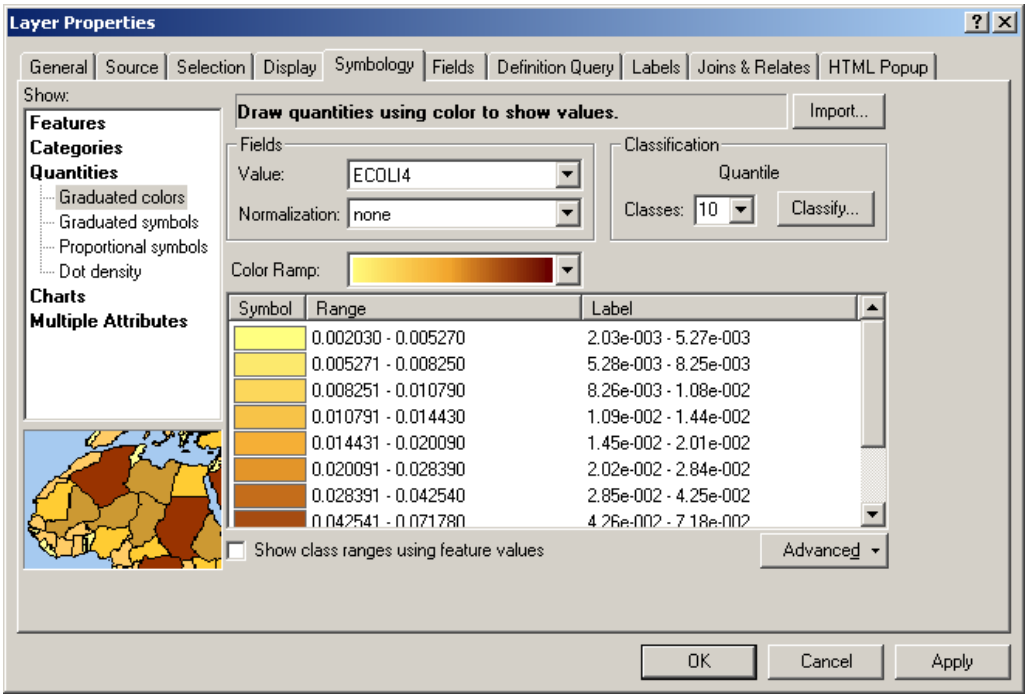


The value will be assigned a default colour ramp and range distribution by ArcGIS.

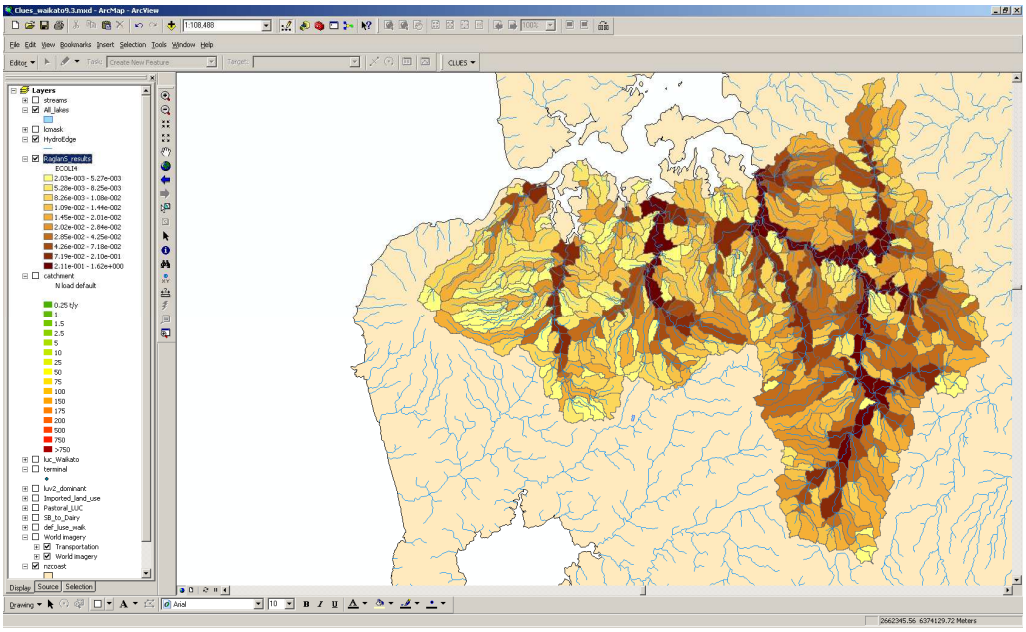
2. To change the distribution, click on the *Classify* button and make the appropriate changes (here the range is split into deciles).



3. To change the colour ramp, select from the *Color Ramp* drop down menu. Labels for each class can be adjusted manually by clicking on each in turn or by clicking on Label to bring up format options (here scientific format with two decimal places).



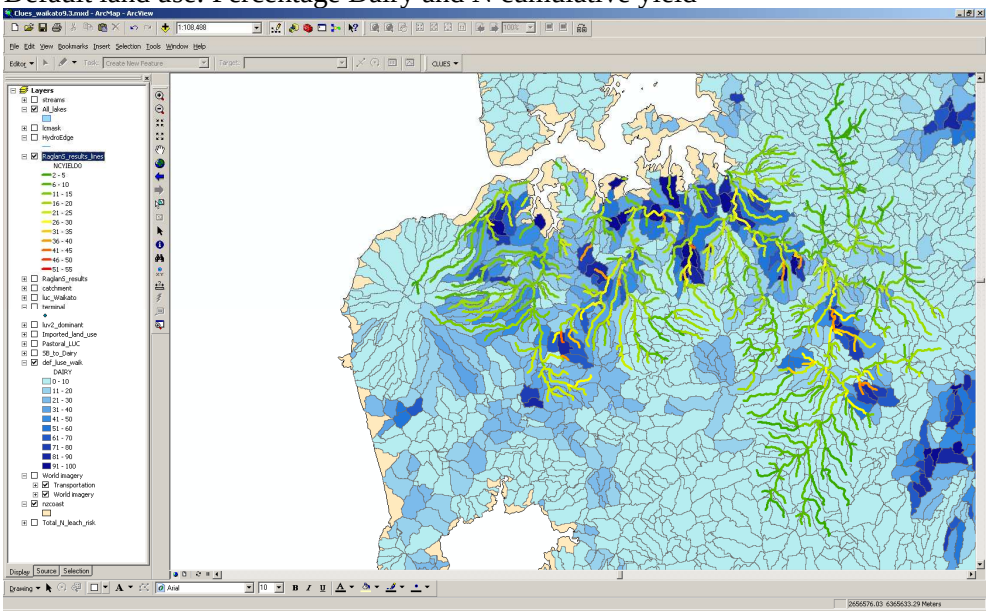
4. Click *OK* to display the result.



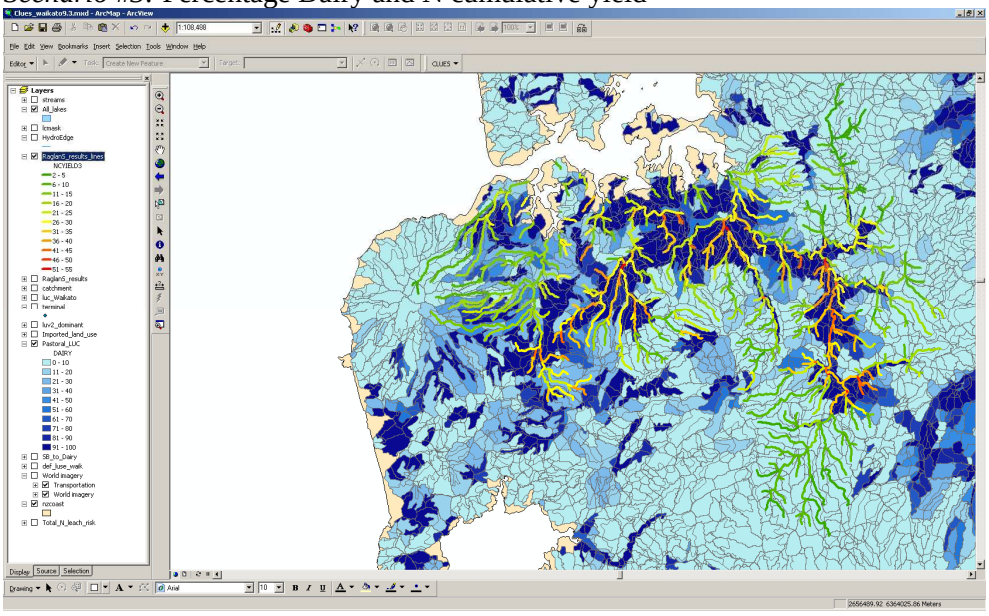
7.2.1 Combining layers

Exporting results, adding new layers and changing symbology offers powerful ways of displaying results. In this example, river line maps of cumulative N yield for default land use and *Scenario* #3 are displayed against the percentage of dairying as defined in the *def_luse_waik* and *Pastoral_LUC* layers respectively. The yield is displayed for the simulated river reaches from a new layer exported from the *streams* layer (*RaglanS_results_lines.shp*) with a green to red colour ramp which is the same for both examples (0–55 kg/ha/year in intervals of 5 kg/ha/year). The land-use layers have been assigned a blue colour ramp with 10% intervals.

Default land use: Percentage Dairy and N cumulative yield



Scenario #3: Percentage Dairy and N cumulative yield

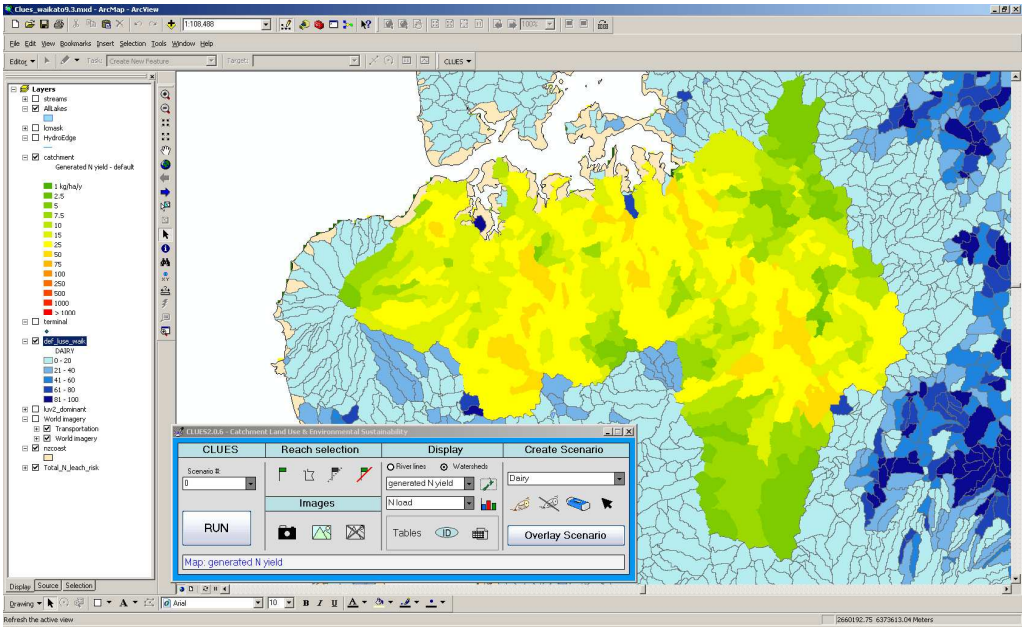


It can be seen that increasing the percentage of dairying increases the downstream cumulative N yield.

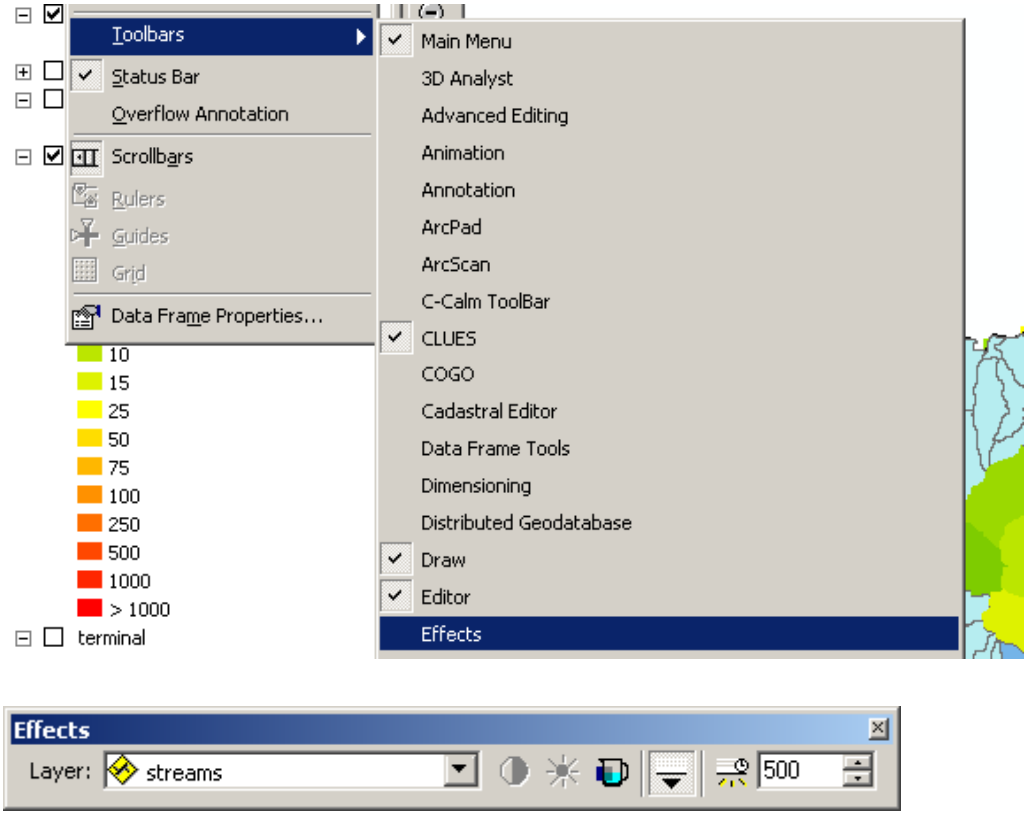
7.3 The Effects Toolbar

The ArcGIS Effects toolbar enables users to quickly compare layers without having to turn layers on or off in the *TOC* or change symbology (i.e., transparency). It is particularly useful for identifying land uses or surface features that could have an impact on water quality. This example will compare N generated yield simulated using the default land use (*Scenario* #0) to the percentage of dairy farming in each sub-catchment (i.e., from the *def_luse_waik* layer with the quantity of dairying displayed with a graduated colour ramp).

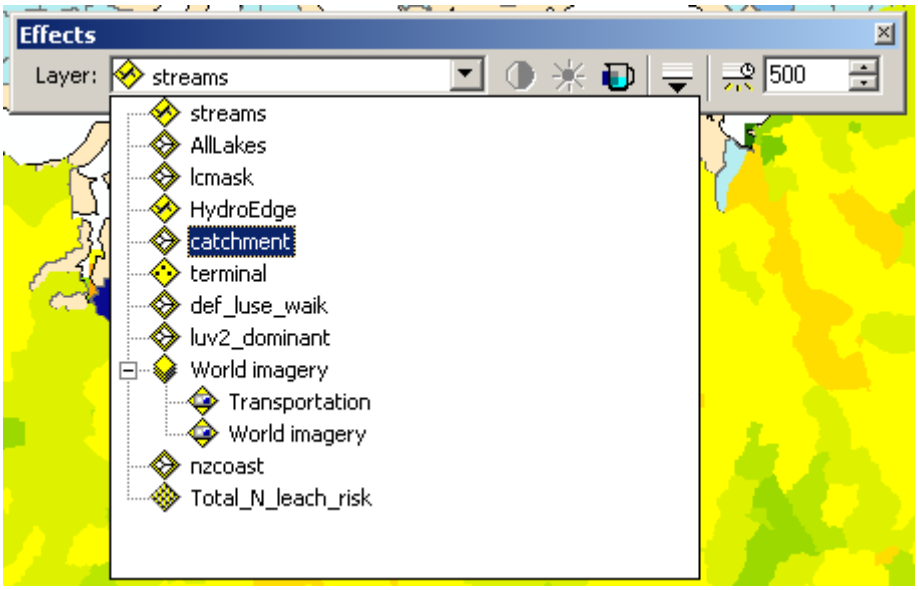
1. Select the layers to be compared by checking them in the *TOC* for display. Here the *catchment* layer showing CLUES results covers the underlying land use layer used to create the scenario.



2. Bring up the *Effects* toolbar by selecting it from toolbars under the *View* menu.



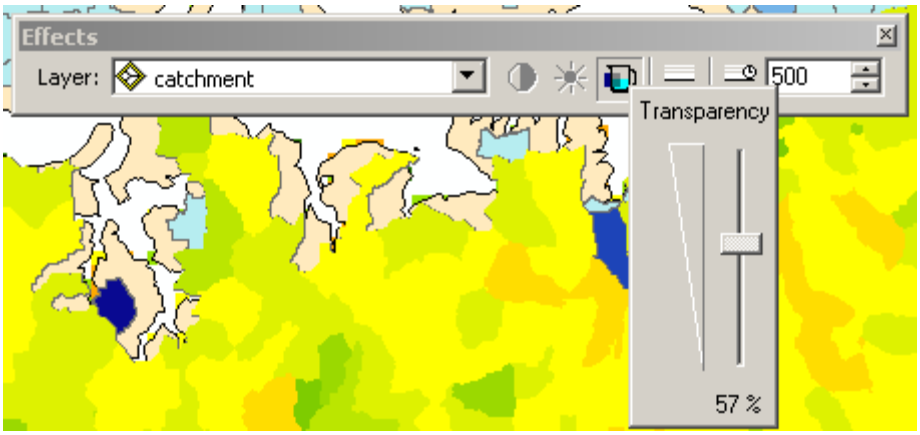
3. Select the upper-most layer to be compared (in this case, *catchment* to show CLUES results) from the *Layer* drop-down menu.



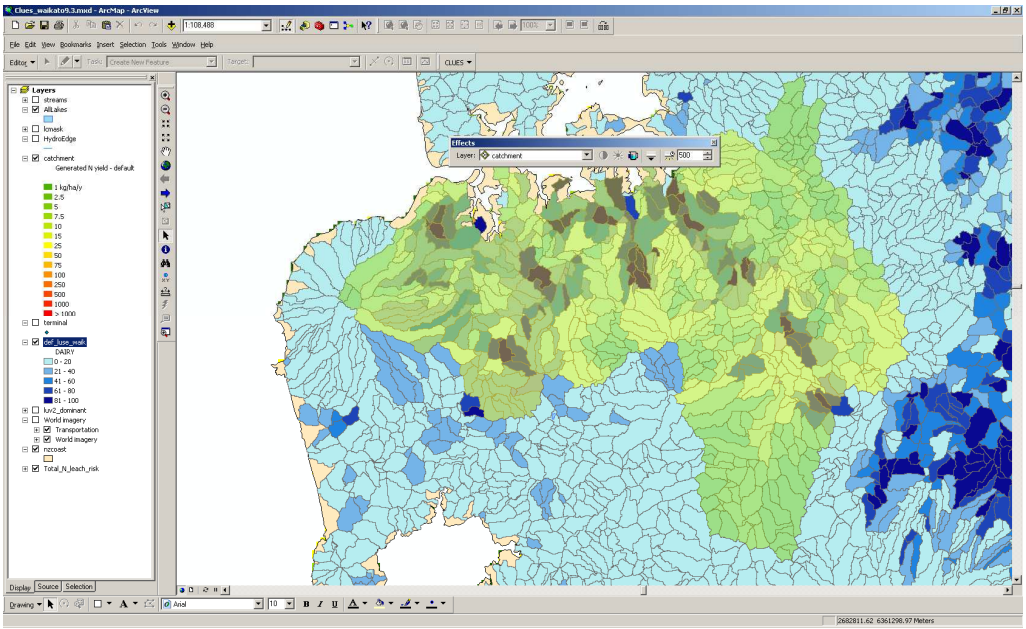
4. Choose the required layers for comparison and select the type of effect from the toolbar.

Transparency

Click the *Transparency* icon to bring up the *Transparency* scale.

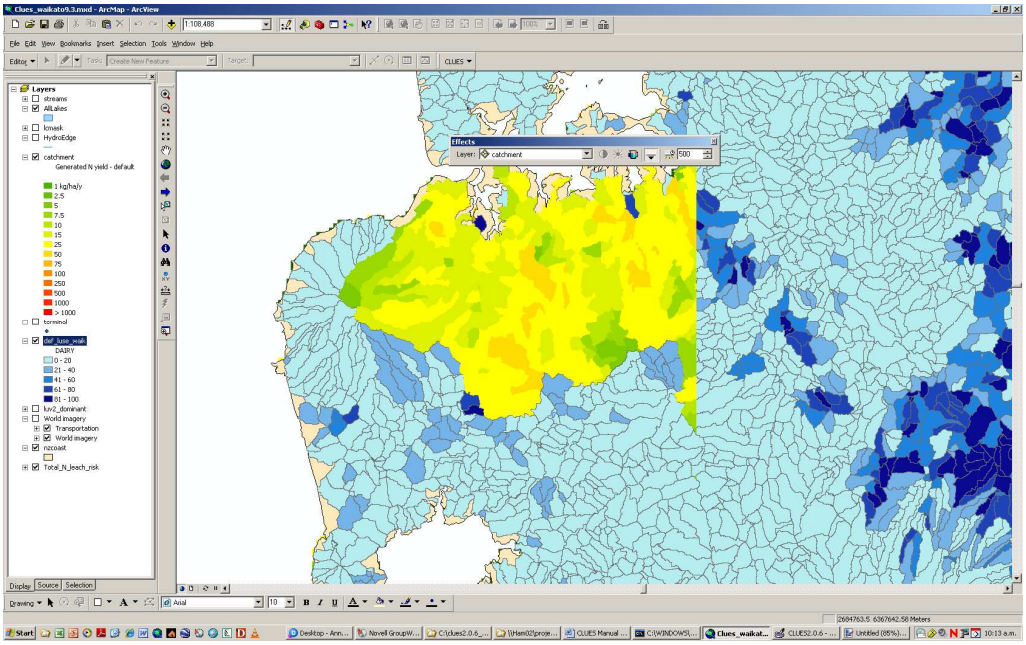


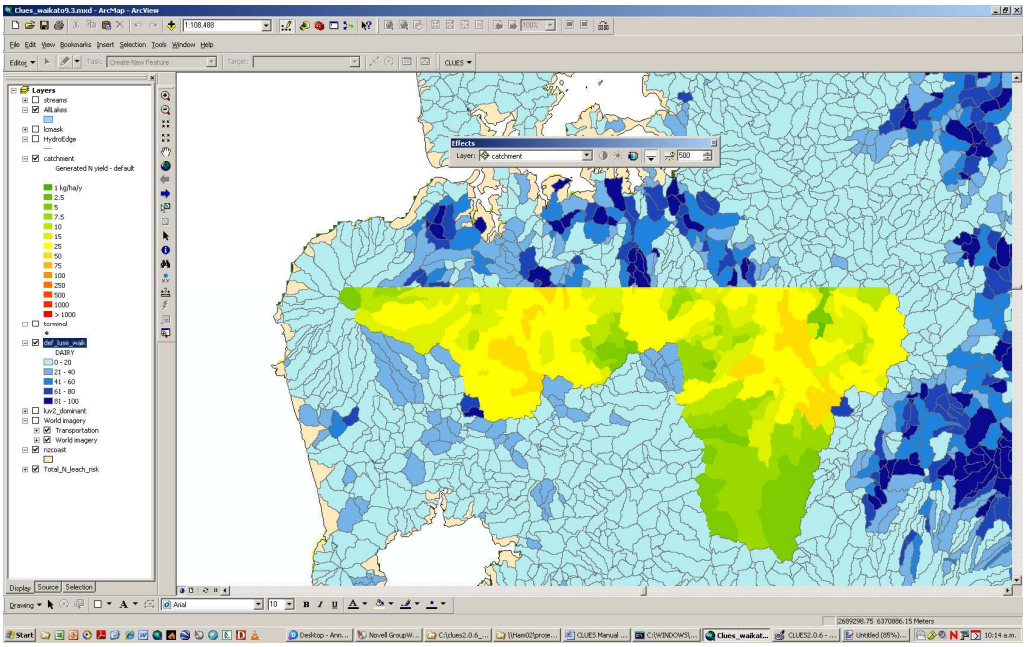
Scroll to the transparency of the selected layer.



Swiping

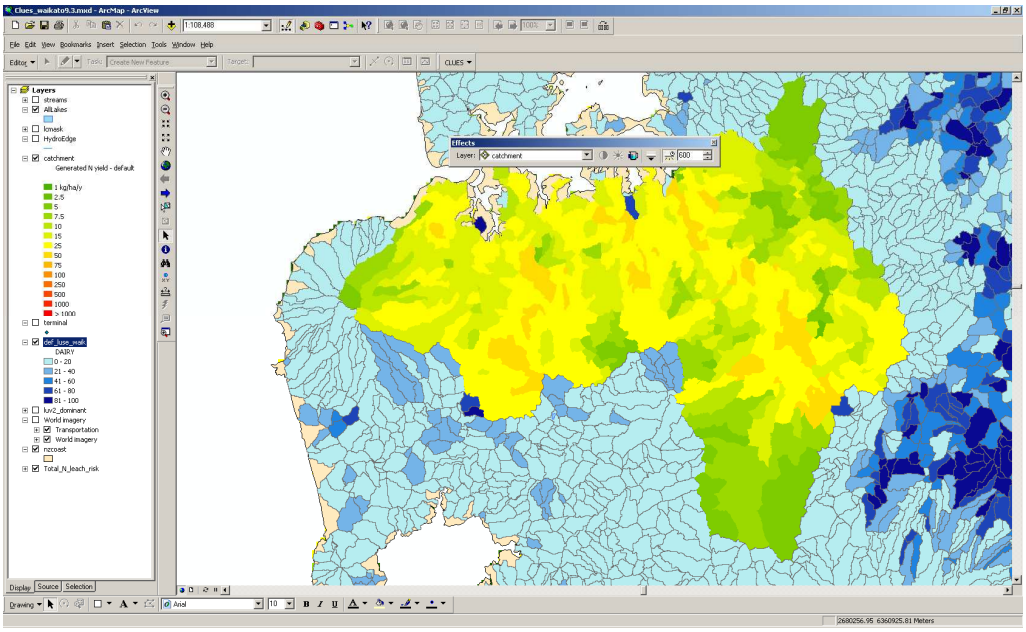
Click the *Swipe* icon. This will change the cursor to an arrow head. Click and drag the mouse to reveal the underlying layer. You can swipe left ◂, right ▸, up ▲ or down ▼.

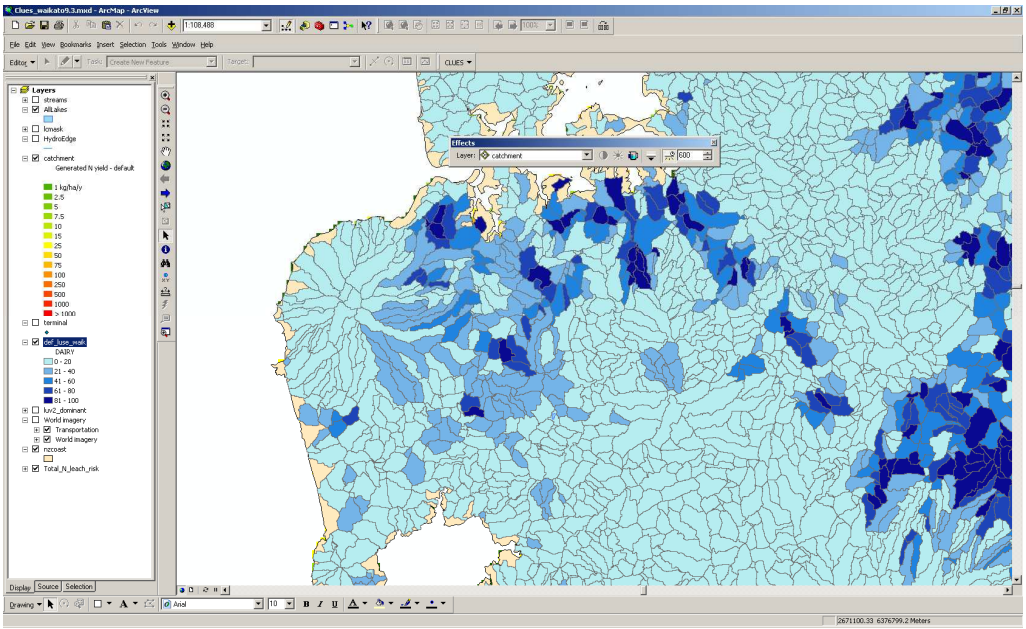




Flickering

Click the *Flicker* icon and set the timer to the speed (here set to 600 milliseconds) between flickers (warning: faster speeds can have a strobing effect)

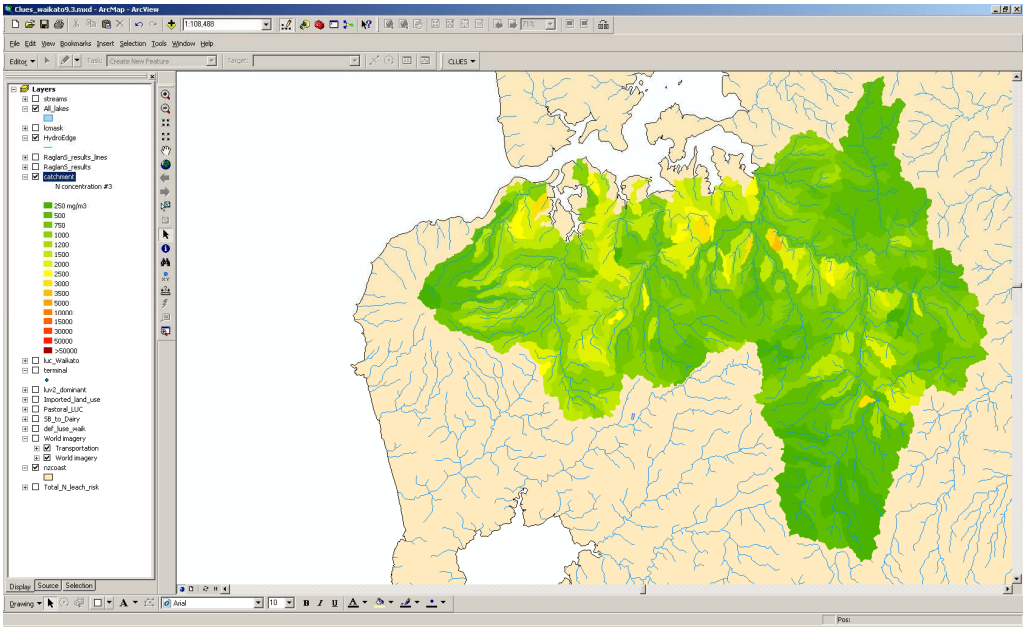




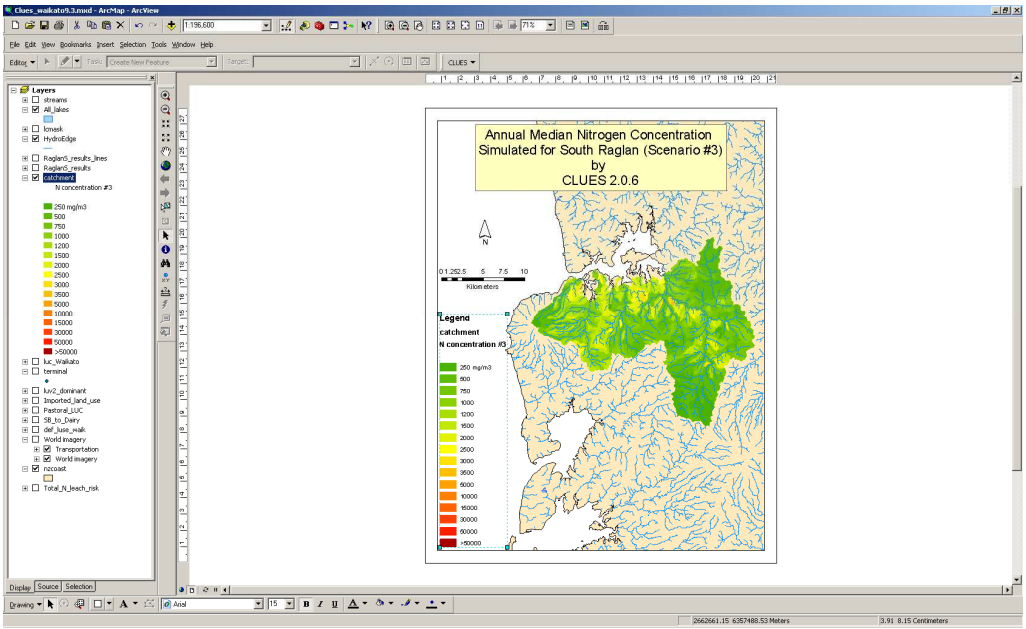
7.4 Making maps

Switching from *Data view* to *Layout view* allows users create maps that can be saved as image files for subsequent display in documents. The tools are standard to ArcGIS. This example is the N concentration for *Scenario* #3 (Pasture_LUC). NOTE, CLUES cannot run in *Layout view*.

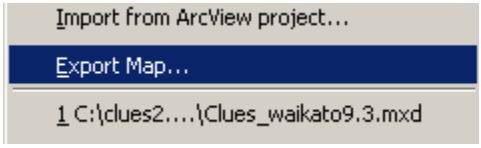
1. Display the results to be mapped and minimise or close the CLUES 2.0.6

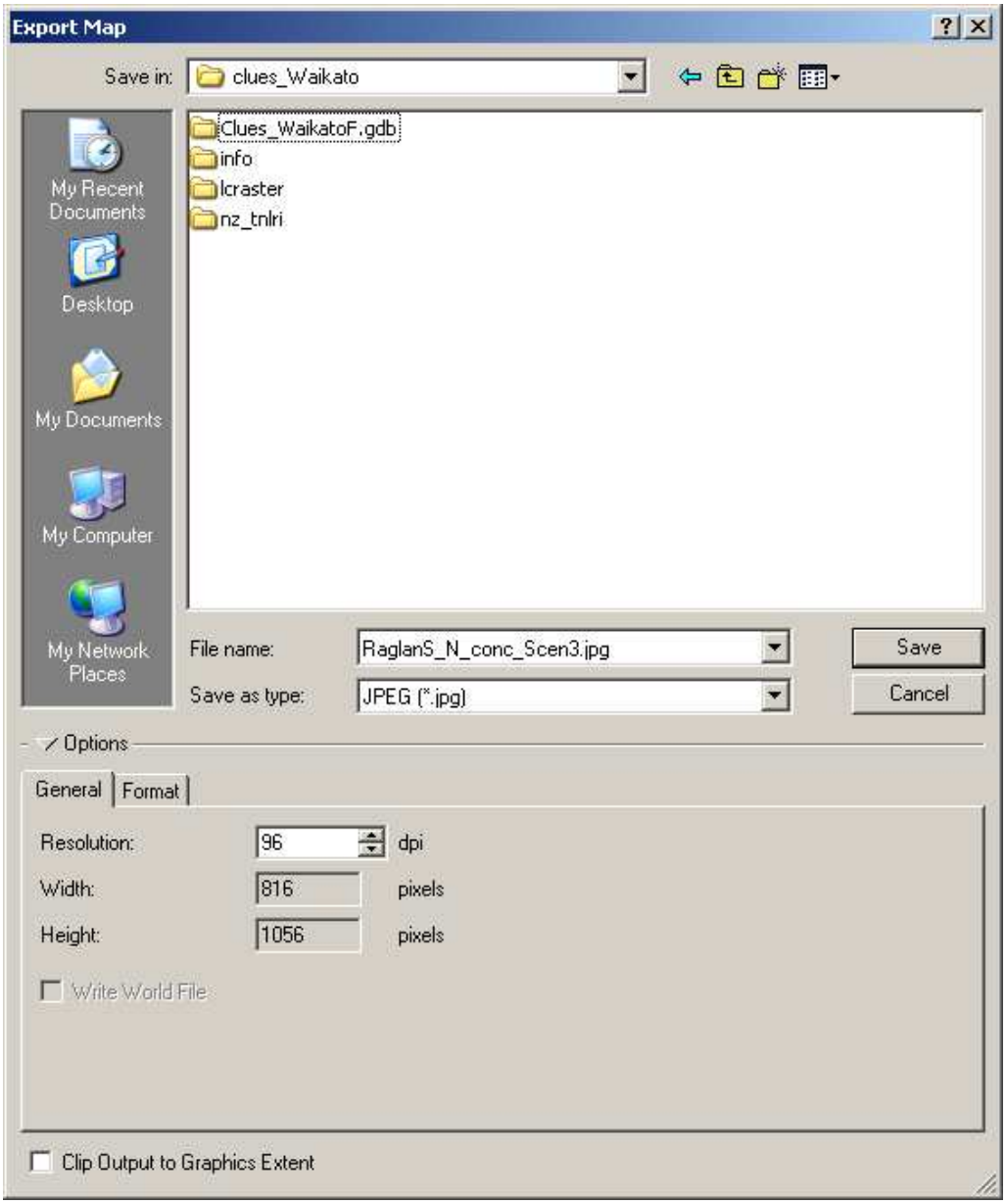


2. Switch to *Layout* view and insert map elements (e.g., scale bar) as required. These elements can be formatted and repositioned for display.

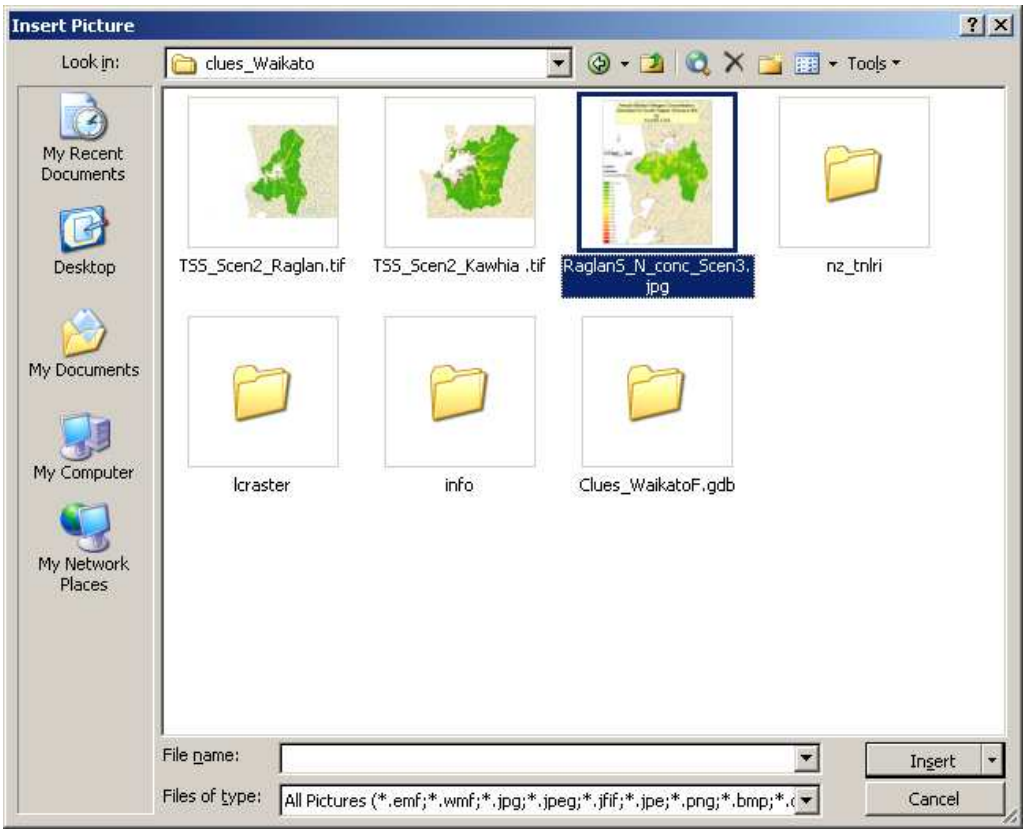


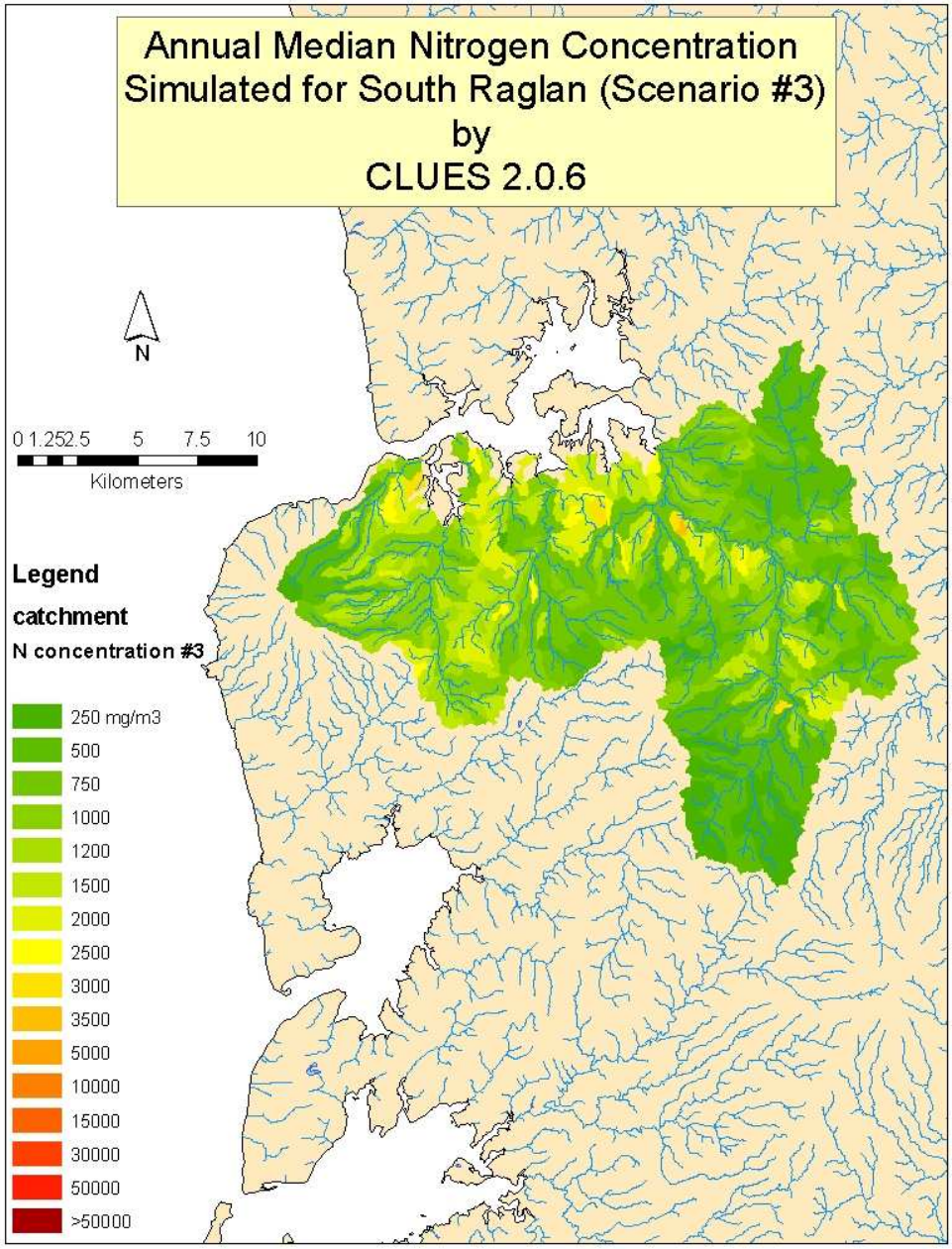
3. Select *Export Map* under the *File* menu to open the *Export Map* dialogue box. Browse to the location for the map and give the map an appropriate mane. Images can be saved in a number of different formats (e.g. jpeg, tiff, giff, bitmaps, PDF etc.). Click *Save.*





4. The map will be saved as an image that can be opened directly in other software packages.




Annual Median Nitrogen Concentration
Simulated for South Raglan (Scenario #3)
by
CLUES 2.0.6
N
0 1.252.5 5 7.5 10
Kilometers
Legend
catchment
N concentration #3
250 mg/m3
500
750
1000
1200
1500
2000
2500
3000
3500
5000
10000
15000
30000
50000
>50000

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Appendix One: Calculation of nutrient concentrations

Concentrations are predicted from loads in the following way. First, the flow weighted concentration, C_{fw} (mg/m^3), can be calculated from the CLUES estimated mean annual load (L, t/year) and the mean annual flow (Q, m^3/s) provided in the CLUES dataset:

$$C_{fw} = \frac{10^9 L}{365.25 \times 86400 Q} \qquad \textbf{Equation 1}$$

Both L and Q can be found for each reach in the *catchment* layer.

The median (time-average) concentration, C_m, is of more practical interest than the flow-weighted concentration. The flow-weighted concentration is nearly always greater than the median, because concentrations typically increase with flow rate. Hence, a new method for determining the ratio of C_{fw} to C_m has been used in CLUES 2.0.6 to estimate C_m. The method was derived from an analysis of concentration and flow data in the National Rivers Water Quality Network (Smith and Maasdam, 1994)[5]. The load for determining C_{fw} was calculated using the methods in Elliott et al. (2005)[6] but using the full 20-year dataset, whereas C_m was taken as the median of the values in the dataset. The ratio of these concentrations, R, was then calculated for each site:

$$R = \frac{C_m}{C_{fw}} \qquad \textbf{Equation 2}$$

Then Boosted Regression Tree statistical regression methods (Elith et al. 2008)[7] were used to predict R nationally as a function of variables which are available in the REC and NIWA extensions to the REC[8]. The final form of the regression used the following variables for N and P respectively (in decreasing order of importance):

[5] Smith, D.G.; Maasdam, R. (1994) New Zealand's National River Water Quality Network 1. Design and physico-chemical characterisation. New Zealand Journal of Marine and Freshwater Research 28: 19–35.

[6] Elliott, A.H.; Alexander, R.B.; Schwarz, G.E.; Shankar, U; Sukias, J.P.S.; McBride, G.B. (2005). Estimation of nutrient sources and transport for New Zealand using the hybrid mechanistic–statistical model SPARROW. Journal of Hydrology (NZ) 44(1): 1–27.

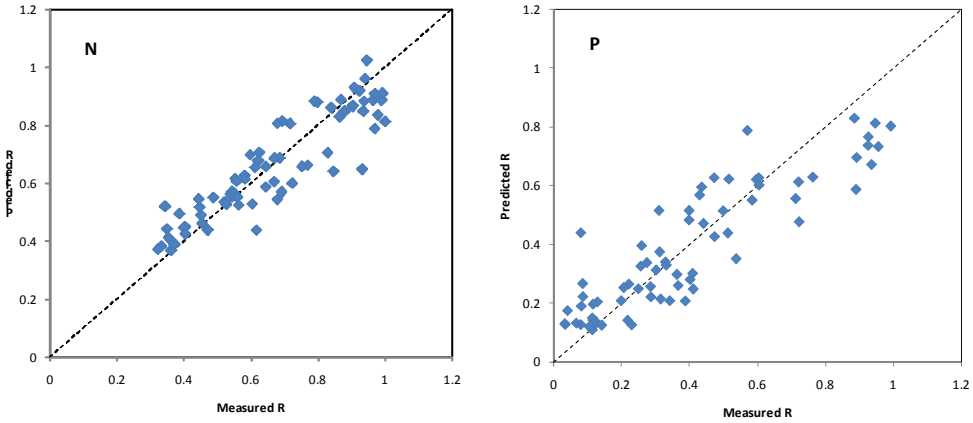
[7] Elith, J.; Leathwick, J.R.; Hastie, T. (2008). A working guide to boosted regression trees. Journal of Animal Ecology 77(4): 802–813.

[8] Leathwick, J.R.; Elith, J.; Rowe, D.; Julian, K. (2009). Robust planning for restoring diadromous fish species in New Zealand ga ss lowland rivers and streams. New Zealand journal of marine and freshwater research 43(3): 659-671.

- N: Sediment yield; Mean annual flow divided by mean annual flood; average temperature in the catchment; fraction of hard-rock geology in the upstream catchment

- P: Sediment yield; Mean annual flood flow; Ratio of sediment load to phosphorus load; Mean annual flow; percent of native vegetation in the upstream catchment.

The fit of the regression to the data is shown in the figures below. Clearly, this method involves errors in the estimate of R, as indicated in the figures, which will lead to errors in predictions of concentrations. For example, for an error in R of 0.2 and a predicted value of 0.8, the error in concentration will be 25% (which is in addition to errors in calculating C_{fw}).



Since the predictor variables are available for each reach nationally, *R* can be found for each reach. C_m can then be calculated for each reach using Equations 1 and 2.

Appendix Two: Result fields listed in the *Catchment layer*

There are 84 CLUES result fields (14 sets of results for the default and five land use change scenarios) in the *catchment* layer. The order they appear in the layer attribute table is as follows:

Name	Alias	Description	Unit	Scenario
CFS1	CFS($) – #1	cash flow surplus	NZD$	1
CFS2	CFS($) – #2	cash flow surplus	NZD$	2
CFS3	CFS($) – #3	cash flow surplus	NZD$	3
CFS4	CFS($) – #4	cash flow surplus	NZD$	4
CFS5	CFS($) – #5	cash flow surplus	NZD$	5
GDP1	GDP($) – #1	gross domestic product	NZD$	1
GDP2	GDP($) – #2	gross domestic product	NZD$	2
GDP3	GDP($) – #3	gross domestic product	NZD$	3
GDP4	GDP($) – #4	gross domestic product	NZD$	4
GDP5	GDP($) – #5	gross domestic product	NZD$	5
FTE1	FTE – #1	Full time equivalents	dimensionless	1
FTE2	FTE – #2	Full time equivalents	dimensionless	2
FTE3	FTE – #3	Full time equivalents	dimensionless	3
FTE4	FTE – #4	Full time equivalents	dimensionless	4
FTE5	FTE – #5	Full time equivalents	dimensionless	5
CFS0	CFS($) – default	cash flow surplus	NZD$	0
GDP0	GDP($) – default	gross domestic product	NZD$	0
FTE0	FTE – default	Full time equivalents	dimensionless	0
NLOAD1	N (t/y) – #1	total N load	tonnes/year	1
NLOAD2	N (t/y) – #2	total N load	tonnes/year	2
NLOAD3	N (t/y) – #3	total N load	tonnes/year	3
NLOAD4	N (t/y) – #4	total N load	tonnes/year	4
NLOAD5	N (t/y) – #5	total N load	tonnes/year	5
PLOAD1	P (t/y) – #1	total P load	tonnes/year	1
PLOAD2	P (t/y) – #2	total P load	tonnes/year	2
PLOAD3	P (t/y) – #3	total P load	tonnes/year	3

Name	Alias	Description	Unit	Scenario
PLOAD4	P (t/y) – #4	total P load	tonnes/year	4
PLOAD5	P (t/y) – #5	total P load	tonnes/year	5
NLOAD0	N (t/y) – default	total N load	tonnes/year	0
PLOAD0	P (t/y) – default	total P load	tonnes/year	0
NYIELD1	N yield (kg/ha/y) – #1	cumulative total N yield	kg/ha/year	1
NYIELD2	N yield (kg/ha/y) – #2	cumulative total N yield	kg/ha/year	2
NYIELD3	N yield (kg/ha/y) – #3	cumulative total N yield	kg/ha/year	3
NYIELD4	N yield (kg/ha/y) – #4	cumulative total N yield	kg/ha/year	4
NYIELD5	N yield (kg/ha/y) – #5	cumulative total N yield	kg/ha/year	5
NYIELD0	N yield (kg/ha/y) – default	cumulative total N yield	kg/ha/year	0
PYIELD0	P yield (kg/ha/y) – default	cumulative total P yield	kg/ha/year	0
PYIELD1	P yield (kg/ha/y) – #1	cumulative total P yield	kg/ha/year	1
PYIELD2	P yield (kg/ha/y) – #2	cumulative total P yield	kg/ha/year	2
PYIELD3	P yield (kg/ha/y) – #3	cumulative total P yield	kg/ha/year	3
PYIELD4	P yield (kg/ha/y) – #4	cumulative total P yield	kg/ha/year	4
PYIELD5	P yield (kg/ha/y) – #5	cumulative total P yield	kg/ha/year	5
ECOLI0	peta E.coli per year–default	load of *E. coli*	10^{15} organisms/year	0
ECOLI1	peta E.coli per year–#1	load of *E. coli*	10^{15} organisms/year	1
ECOLI2	peta E.coli per year–#2	load of *E. coli*	10^{15} organisms/year	2
ECOLI3	peta E.coli per year–#3	load of *E. coli*	10^{15} organisms/year	3
ECOLI4	peta E.coli per year–#4	load of *E. coli*	10^{15} organisms/year	4
ECOLI5	peta E.coli per year–#5	load of *E. coli*	10^{15} organisms/year	5
NCYIELD0	gen. N yield(kg/ha/y)–default	generated total N yield	kg/ha/year	0
NCYIELD1	gen. N yield(kg/ha/y)–#1	generated total N yield	kg/ha/year	1
NCYIELD2	gen. N yield(kg/ha/y)–#2	generated total N yield	kg/ha/year	2
NCYIELD3	gen. N yield(kg/ha/y)–#3	generated total N yield	kg/ha/year	3
NCYIELD4	gen. N yield(kg/ha/y)–#4	generated total N yield	kg/ha/year	4
NCYIELD5	gen. N yield(kg/ha/y)–#5	generated total N yield	kg/ha/year	5
PCYIELD0	gen. P yield(kg/ha/y)–default	generated total P yield	kg/ha/year	0
PCYIELD1	gen. P yield(kg/ha/y)–#1	generated total P yield	kg/ha/year	1
PCYIELD2	gen. P yield(kg/ha/y)–#2	generated total P yield	kg/ha/year	2

Name	Alias	Description	Unit	Scenario
PCYIELD3	gen. P yield(kg/ha/y)–#3	generated total P yield	kg/ha/year	3
PCYIELD4	gen. P yield(kg/ha/y)–#4	generated total P yield	kg/ha/year	4
PCYIELD5	gen. P yield(kg/ha/y)–#5	generated total P yield	kg/ha/year	5
SED0	SED (t/y) – default	total suspended solids (TSS) load	tonnes/year	0
SED1	SED (t/y) – #1	total suspended solids (TSS) load	tonnes/year	1
SED2	SED (t/y) – #2	total suspended solids (TSS) load	tonnes/year	2
SED3	SED (t/y) – #3	total suspended solids (TSS) load	tonnes/year	3
SED4	SED (t/y) – #4	total suspended solids (TSS) load	tonnes/year	4
SED5	SED (t/y) – #5	total suspended solids (TSS) load	tonnes/year	5
SEDYIELD0	gen. SED yield(kg/ha/y)–default	generated TSS yield	kg/ha/year	0
SEDYIELD1	gen. SED yield(kg/ha/y)–#1	generated TSS yield	kg/ha/year	1
SEDYIELD2	gen. SED yield(kg/ha/y)–#2	generated TSS yield	kg/ha/year	2
SEDYIELD3	gen. SED yield(kg/ha/y)–#3	generated TSS yield	kg/ha/year	3
SEDYIELD4	gen. SED yield(kg/ha/y)–#4	generated TSS yield	kg/ha/year	4
SEDYIELD5	gen. SED yield(kg/ha/y)–#5	generated TSS yield	kg/ha/year	5
NCONC0	N Conc(mg/m3) – default	median N concentration	mg/m^3	0
NCONC1	N Conc(mg/m3) – #1	median N concentration	mg/m^3	1
NCONC2	N Conc(mg/m3) – #2	median N concentration	mg/m^3	2
NCONC3	N Conc(mg/m3) – #3	median N concentration	mg/m^3	3
NCONC4	N Conc(mg/m3) – #4	median N concentration	mg/m^3	4
NCONC5	N Conc(mg/m3) – #5	median N concentration	mg/m^3	5
PCONC0	P Conc(mg/m3) – default	median P concentration	mg/m^3	0
PCONC1	P Conc(mg/m3) – #1	median P concentration	mg/m^3	1
PCONC2	P Conc(mg/m3) – #2	median P concentration	mg/m^3	2
PCONC3	P Conc(mg/m3) – #3	median P concentration	mg/m^3	3
PCONC4	P Conc(mg/m3) – #4	median P concentration	mg/m^3	4
PCONC5	P Conc(mg/m3) – #5	median P concentration	mg/m^3	5