



Phosphorus Land Use and Slope (PLUS+) Model

User Guide

&

Computer Code (Version 1.6)

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1. INTRODUCTION

The Macaulay Land Use Research Institute (MLURI), since April 2011 The James Hutton Institute, developed the Phosphorus Land Use and Slope (PLUS) model in the 1990's in association with the Forth River Purification Board and with funding assistance from Scottish Natural Heritage. In conjunction with a hindcasted national land cover (circa 1850) dataset PLUS attempted to discern the relationship between anthropogenic drivers of nutrient enrichment (especially Phosphorus [P]) and trophic status of standing waters in Scotland. This effort was carried out for 170 lochs and proved to be a robust investigation. There was interest in using the model to undertake further assessment of loch phosphorus concentrations and how these are affected by changes in land cover and point sources of P. However, the PLUS model was based on old GIS technology and lacked any kind of user friendly interface as well as no facilities for maintaining records of simulations in a central database. Work has recently been completed to address these issues and this report aims to provide a user guide to aid utilization of the model via the new user interface.

While appropriate checks and precautions have been taken during design, execution and testing of PLUS+, The James Hutton Institute cannot be held responsible for any consequences arising from the use or miss-use of the model, or any part therein. Users of PLUS+ are strongly advised to confirm the results obtained from PLUS+ using an alternative method of calculation.

2. SCOPE OF THE MODEL

2.1 Purpose

PLUS+ is a GIS based system that provides the ability to investigate present day P concentrations in standing waters in Scotland through source apportionment techniques. The model has the potential to be used in investigating consents, sensitivity analysis and scenario analysis using changing land cover situations and point source P, storing input and output parameters in a centralized database.

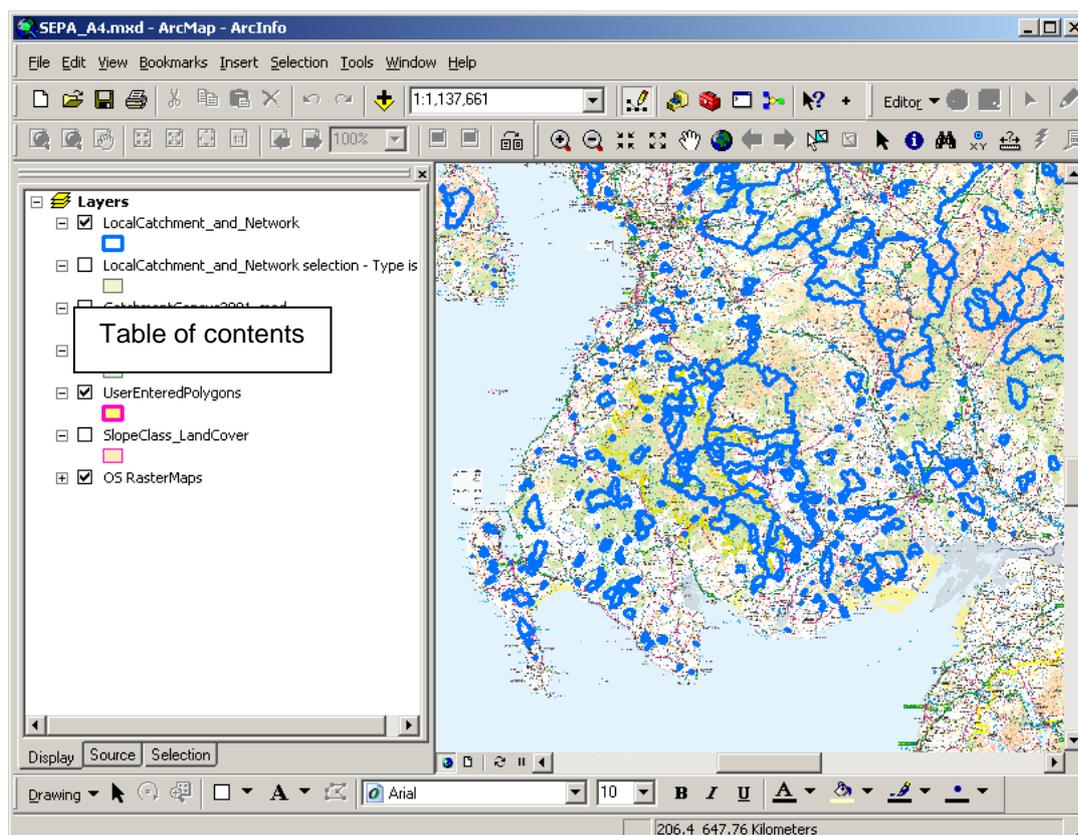
Scenario modelling options include:

- Land cover
 - Ability to overlay new land cover data.
 - Ability to change P loss coefficients.
 - Ability to make bulk changes to land cover areas.
- Point sources
 - Ability to change waste water treatment works (WWTW) P input through altering urban population and loss coefficient.
 - Ability to change septic tank P input through altering rural population and loss coefficient.
 - Addition of total P from other point sources.

It is emphasised that the model is designed to consider standing waters.

2.2 The model structure and data

The application uses the ArcMap Table of Contents ('Display' and 'Source', see below) to access data.



In order to be used in the application the tables, shape files and feature classes must first be loaded into the Table of Contents. The application uses the path to the data which is stored by ArcMap in the table of contents, giving flexibility of data location, including access to files across networks, and avoids issues of data concurrency.

There are two ESRI personal geodatabases (PGDB): SourceData.mdb and ScenarioData.mdb. SourceData.mdb contains the following tables:

1. CatchmentSewage (Urban and rural populations and their associated P load)
2. CatchP (Land cover type and area and associated P)
3. Exports (P look up table for land cover/slope combinations)
4. FlowRouting (Loch flow relationships)
5. LoadPrecursor (Loch attributes)
6. PerCapitaTPLoads (P look up table for urban and rural P load)
7. TPBreakPoints (Water quality P break points)

and the following feature classes:

1. LocalCatchment_and_Network (Catchment polygons, and their attributes)
2. SlopeClass_LandCover (Land cover/slope polygons)

Additionally the following tables containing SEPA monitoring information are required:

1. SEPA_detailed_Loch_WB_classification (loch classifications for WBID)
2. SEPA_20XX_loch_class (measured P concentration for specified years XX)

ScenarioData.mdb largely duplicates the SourceData above but with names suffixed with “_S” to denote scenario tables. SlopeClass_LandCover and FlowRouting are not included as they will not be modified. Additionally ScenarioData.mdb includes a table “Scenario”. This table contains all the information to identify and describe the scenario:

1. ScenarioID
2. ScenarioName
3. ScenarioCreator
4. ScenarioCreationDate

5. Comment
6. Region

Note that the two SEPA monitoring tables are not duplicated within the scenario structure so that whether the baseline data or scenario data are being loaded the SEPA tables must be selected first. Additionally, the measured values are not incorporated in the PLUS+ modelling calculations, they are included in the reports and output windows for information and comparison with the modelled values.

Point sources of P added to the model by a user through PLUS+ will be stored in the scenario table PointSource_S. Any number of point sources may be added by the user (only subject to operating system and database restrictions). This table can also be edited manually to add point sources to a scenario. The scenario database does not include a "FlowRouting" table as the topological relationships of lochs will not be modified by any of the scenario creations.

As detailed above, the input and output tables and feature classes are contained in these two personal geodatabases. The software has been written around the use of geodatabases and it is necessary to use these to store the data sets. Attempting to use standalone tables (i.e. tables not stored in a geodatabase) for scenarios will cause the software to crash. However, standalone shapefiles may be used to import modified land cover and the output from the processing of the overlay of the new land cover and the base line land cover will be saved to a user-specified standalone shapefile.

The tables and feature classes in ScenarioData.mdb have the same attribute structure as SourceData.mdb, but with the addition of an attribute "ScenarioID" in each case. This is used to link to the "Scenario" table in the database. These tables are used to store the attribute values from the user created scenarios (including overlays of new land cover data), whether modified or copied from the SourceData.mdb tables.

The application uses a SEPA produced table containing its annually updated loch classifications. PLUS+ searches the table of contents (or source tab) for tables with "SEPA" in their name and adds them to the relevant drop-down menu to allow the user to choose the correct table or to enable modelling the effects with different tables. Within PLUS+ the following field names are expected to be found in the table that the user selects: WATER_BODY_ID and STATUS. The application also uses a SEPA look up table to translate between GB Lakes and Water Body identifiers. In this table the expected field names are: WB_ID and WG_WBID. The application will generate an error message if these fields are not found in the table selected by the user. Note that these tables are also used when data has been loaded from a scenario, so please ensure that they are selected.

SEPA periodically revises the water body breakpoint values. To ensure that PLUS+ is always using the most recent data a second Visual Basic tool has been supplied – frmUpdateBreakPoints. This can be run in the same manner as PLUS+. The user must select the existing breakpoints table from SourceData.mdb (TPBreakPoints), a look-up-table to relate the waterbody ID's and the GB Lakes IDs and the table of updated data. Once the user has selected a table the secondary drop down menus will be populated with the available fields in the table. The revised breakpoint data is to be of the following format: individual records for each of five water quality standards for each water body (so five records for each water body), a field containing the water body ID, a lower limit field, an upper limit field and a numerical field with a value of 1 corresponding to Poor and 5 corresponding to High. Please note that clicking on "Update breakpoints table" will overwrite the table in the SourceData database, so please make a back-up of the table first. PLUS+ will use the TPBreakPoints table in all calculations (including RAG assessment), so please ensure that it contains the correct data.

2.3 Method utilised by model to calculate phosphorus concentrations

2.3.1. Calculation of land cover Phosphorus load

Land Cover of Scotland 1988 (LCS88 data) has been used to represent land cover. Each land cover area was subdivided based on its slope (calculated using Ordnance Survey elevation data) into three slope classifications, low medium and high, see Table 1 for the thresholds used.

Table 1 Slope classification thresholds

Low	0-4 degrees
Medium	4-13 degrees
High	13+ degrees

Phosphorus export coefficients were then assigned for each slope category for each land cover type. The default export coefficients used in PLUS+ are the average of those developed collaboratively between MLURI and the Forth River Purification Board (Table 2). These loss coefficients were calibrated in a project completed for SNIFFER by Ferrier et al. (1996) for all the lochs in the 1995 quinquennial Scottish Water Quality Survey scheme by back calculating the total P load into the waterbody from the best available estimate of total P concentration in the lochs.

Note that the original PLUS model calculated the range of possible P loads based on the minimum and maximum values in Table 2, but that the current version of PLUS+ uses only the mean value and calculates a single load and concentration. It should be considered whether future versions of PLUS+ should incorporate these export coefficient ranges.

Table 2 Land cover and slope P export coefficients (kg ha⁻¹)

Land cover code	Land Cover Description	Export Coefficient for each slope classification											
		Low (Slope code 100)				Medium (Slope code 200)				High (Slope code 300)			
		Match Code	Min	Max	Av.	Match Code	Min	Max	Av.	Match Code	Min	Max	Av.
1	water	101	0.07	0.20	0.135	201	0.00	0.00	0.000	301	0.00	0.00	0.000
2	wetland	102	0.02	0.15	0.085	202	0.00	0.00	0.000	302	0.00	0.00	0.000
3	blanket bog & peatland	103	0.01	0.03	0.020	203	0.02	0.04	0.030	303	0.03	0.05	0.040
4	arable	104	0.40	1.08	0.740	204	0.74	1.54	1.140	304	1.08	2.00	1.540
5	improved grassland	105	0.20	0.44	0.320	205	0.32	0.62	0.470	305	0.44	0.80	0.620
6	coarse grassland	106	0.04	0.08	0.060	206	0.06	0.12	0.090	306	0.08	0.15	0.115
7	smooth grassland	107	0.04	0.08	0.060	207	0.06	0.12	0.090	307	0.08	0.15	0.115
8	heather all types	108	0.04	0.08	0.060	208	0.06	0.12	0.090	308	0.08	0.15	0.115
9	bracken	109	0.04	0.08	0.060	209	0.06	0.12	0.090	309	0.08	0.15	0.115
10	cliffs	110	0.00	0.00	0.000	210	0.00	0.00	0.000	310	0.01	0.08	0.045
11	montane vegetation	111	0.01	0.04	0.025	211	0.02	0.06	0.040	311	0.04	0.08	0.060
12	low scrub	112	0.10	0.18	0.140	212	0.14	0.24	0.190	312	0.18	0.30	0.240
13	broadleaved woodland	113	0.10	0.20	0.150	213	0.15	0.28	0.215	313	0.20	0.35	0.275
14	mixed woodland	114	0.08	0.17	0.125	214	0.12	0.23	0.175	314	0.17	0.30	0.235
15	coniferous plantation	115	0.06	0.14	0.100	215	0.10	0.19	0.145	315	0.14	0.25	0.195
16	recently ploughed land	116	0.40	0.72	0.560	216	0.56	0.96	0.760	316	0.72	1.20	0.960
17	woodland recently felled	117	0.20	0.52	0.360	217	0.36	0.76	0.560	317	0.52	1.00	0.760
18	open canopy young plantation	118	0.08	0.17	0.125	218	0.12	0.23	0.175	318	0.17	0.30	0.235
19	ripping	119	0.25	0.35	0.300	219	0.30	0.43	0.365	319	0.35	0.50	0.425
20	estuary	120	0.00	0.00	0.000	220	0.00	0.00	0.000	320	0.00	0.00	0.000
21	salt marsh	121	0.00	0.00	0.000	221	0.00	0.00	0.000	321	0.00	0.00	0.000
22	duneland	122	0.00	0.00	0.000	222	0.00	0.00	0.000	322	0.00	0.00	0.000
23	maritime grasslands & heaths	123	0.00	0.00	0.000	223	0.00	0.00	0.000	323	0.00	0.00	0.000
24	airfields	124	0.00	0.00	0.000	224	0.00	0.00	0.000	324	0.00	0.00	0.000
25	recreational land	125	0.00	0.00	0.000	225	0.00	0.00	0.000	325	0.00	0.00	0.000
26	quarries	126	0.00	0.00	0.000	226	0.00	0.00	0.000	326	0.00	0.00	0.000
27	factories & urban	127	0.80	1.96	1.380	227	1.38	2.83	2.105	327	1.96	3.70	2.830
28	other land	128	0.00	0.00	0.000	228	0.00	0.00	0.000	328	0.00	0.00	0.000
29	road & rail	129	0.00	0.00	0.000	229	0.00	0.00	0.000	329	0.00	0.00	0.000
0	NULL	100	0.00	0.00	0.000	200	0.00	0.00	0.000	300	0.00	0.00	0.000

2.3.2. Calculation of point source Phosphorus load

The default model output is based on the 2001 census data for which a population density of 0.3 people per hectare has been used to define a threshold between urban and rural population. All waste water for urban populations is assumed to reach the surface water body via waste water treatment works (WWTW) and a per capita P load rate (loss coefficient) has been defined by default as 0.9125 kg P per capita. Waste water from rural populations is assumed to enter the surface water body via septic tanks and a per capita P load rate (loss coefficient) has been defined as a default value of 0.25 kg P per capita.

Table 3 Default point source values

Rural/urban population threshold	0.3 per hectare
Urban Loss Coefficient	0.9125 per capita
Rural Loss Coefficient	0.25 per capita

It is assumed that the entire population within the local catchment and only the population within the local catchment contributed P to the surface water. Population in the network of connected catchments is routed via any upstream linked surface water body using the FlowRouting table and information in the LocalCatchment_and_Network feature class to identify the flow network. The actual location of the WWTW is not modelled in PLUS+.

2.3.3. Calculation of surface water total P concentration

Firstly the overall total P load to a waterbody is calculated from summing the estimates of point sources, land cover total P load (see section 2.3.1 and 2.3.2) and P from upstream lochs. This total load is then used to calculate an in-lake total P concentration using OECD (Eutrophication of Waters, Paris 1982) equations (equation 1).

$$[TP] = a \left(\frac{J / R}{1 + \sqrt{T_w}} \right)^b$$

(Equation 1)

where [TP] is the loch total P concentration in micrograms per litre (µg/l), J is the sum of inputs of P in milligrams per year (mg/yr), T_w is the water residence time in years and a and b are model parameters.

For lochs with a mean depth of ≥ 3 m, (a, b) = (1.55, 0.82). For shallow lochs with a mean depth < 3 m, (a, b) = (1.02, 0.88). The values a and b for each water body are read from the LoadPrecursor table. Measured or modelled mean depths are available for all lochs are also in the LoadPrecursor data set.

The water residence time, T_w is calculated as follows:

$$T_w = \frac{A\bar{z}}{R}$$

(Equation 2)

where A is the area of the loch in square metres (m²), \bar{z} is the mean depth in meters and R is the runoff in cubic metres per year (m³/yr). Runoff is available for all lochs in the database. It is calculated in the following manner:

$$R = jA_L + \sum R_{Up}$$

(Equation 3)

where j is the local runoff in m/yr (this value was taken from the model NIRAMS [Dunn 2004]), A is the local catchment area in m^2 and sum of R_{Up} is the sum of upstream runoff which can be calculated from upstream inflows.

The sum of inputs of phosphorus, J , is calculated in the following manner:

$$J = A_L \sum p_i L_i + s + x + y + \sum R_{Up} [TP]_{Up}$$

(Equation 4)

where the first term is the sum of the different phosphorus loads for the different proportions of land cover classes, s is the sewage load (WWTW and septic tanks), x is the sum of any additional point source inputs and y is an alteration that a user may wish to make when running a scenario. The last term is the sum of upstream inputs. The equation is solved in a cascading manner, starting with 0 Strahler order lochs and proceeding down a chain of connected catchments (each order summing the relevant and topologically determined upstream orders), making it possible to simulate TP concentrations for a series of connected lochs.

3. USING THE MODEL

3.1 Hardware and software requirements and installation

In addition to the personal geodatabases SourceData.mdb and ScenarioData.mdb the VBA form frmCatch, SEPA tables described above and the SEPA ArcMap template SEPA_A4.mxd are also required. The form contains the interface and the programming code of the application. The specified MXD file is required to ensure that the report formatting is correct. The application was written in the VBA environment of ArcGIS version 9.3.1 and has subsequently been updated to 10.2. It is possible that the application will run on older versions of ArcMap, but this has not been tested. The application does not have any dependence on an ESRI extension. The VB code has been extensively commented throughout.

The form should be imported into Project → Normal within the VBA environment. In some installations the Visual Basic environment may be unavailable (in ArcMap Tools → Macros → Visual Basic Editor will be greyed-out). If this is the case please contact your IT department to request VBA installation using the following two files: "VBAOF11.msi" and "VBAOF11I.msi ". Note that for versions 10.1 and 10.2 of ArcGIS an additional VBA licence is required, see Appendix D for more information.

In some installations there may be missing references. This will be indicated by PLUS+ failing to load data with an error message such as a library error on a command such as "Mid" within the computer code. This can be corrected in the Microsoft Visual Basic editor by selecting Tools → References and then by scrolling down the list of Available References and removing ticks from any references which are described as "MISSING". Note that the PLUS+ form must be closed for the References dialog to become available.

Should access to the application be required from a custom user interface button the code in Appendix A should be inserted into the ArcMap 'ThisDocument' object in Normal.mxt.

The VBA application requires Microsoft Windows Common Controls 6.0 (SP6) – this is in the library mscomctl.ocx. If this reference is not listed under the Microsoft Visual Basic section of ArcGIS (Tools → References) it may be necessary to download and install this library from Microsoft or run it from the icon below. The reference can be enabled in Tools → References within the Visual Basic environment (you may have to browse for the control – note that the default file type filter should be changed to 'ActiveX Controls (*.ocx)' in the file type filter).



VisualBasic6-KB896559-v1-ENU.exe

Note that following a modification to the system or ArcGIS installation that PLUS+ will possibly fail to load with an automation error as follows:



To solve this reinstall the OCX library from this Word file using the VB6 executable above.

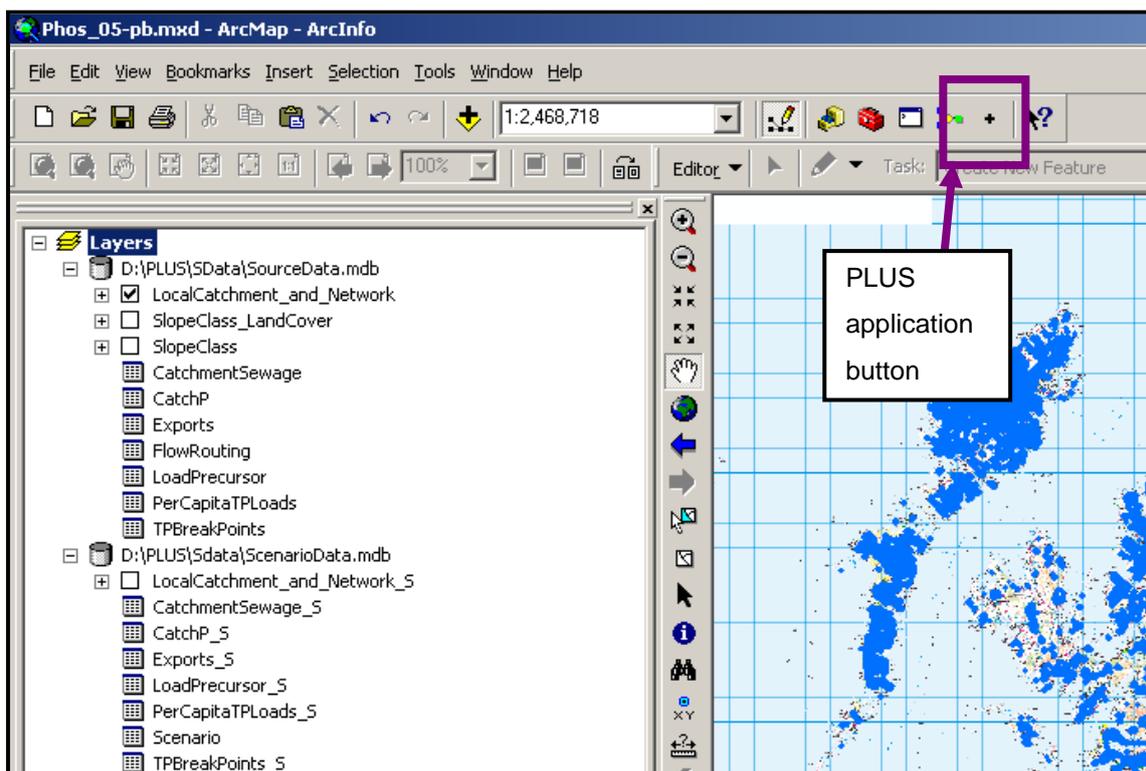
The folder 'c:\temp' is used for the storage of temporary files during the intersection of user supplied land cover and source data. Please ensure that the folder exists.

Please refer to ArcMap Help documents for instructions on customising ArcMap to include a button for the application. The code in Appendix A, below, expects the button to be named

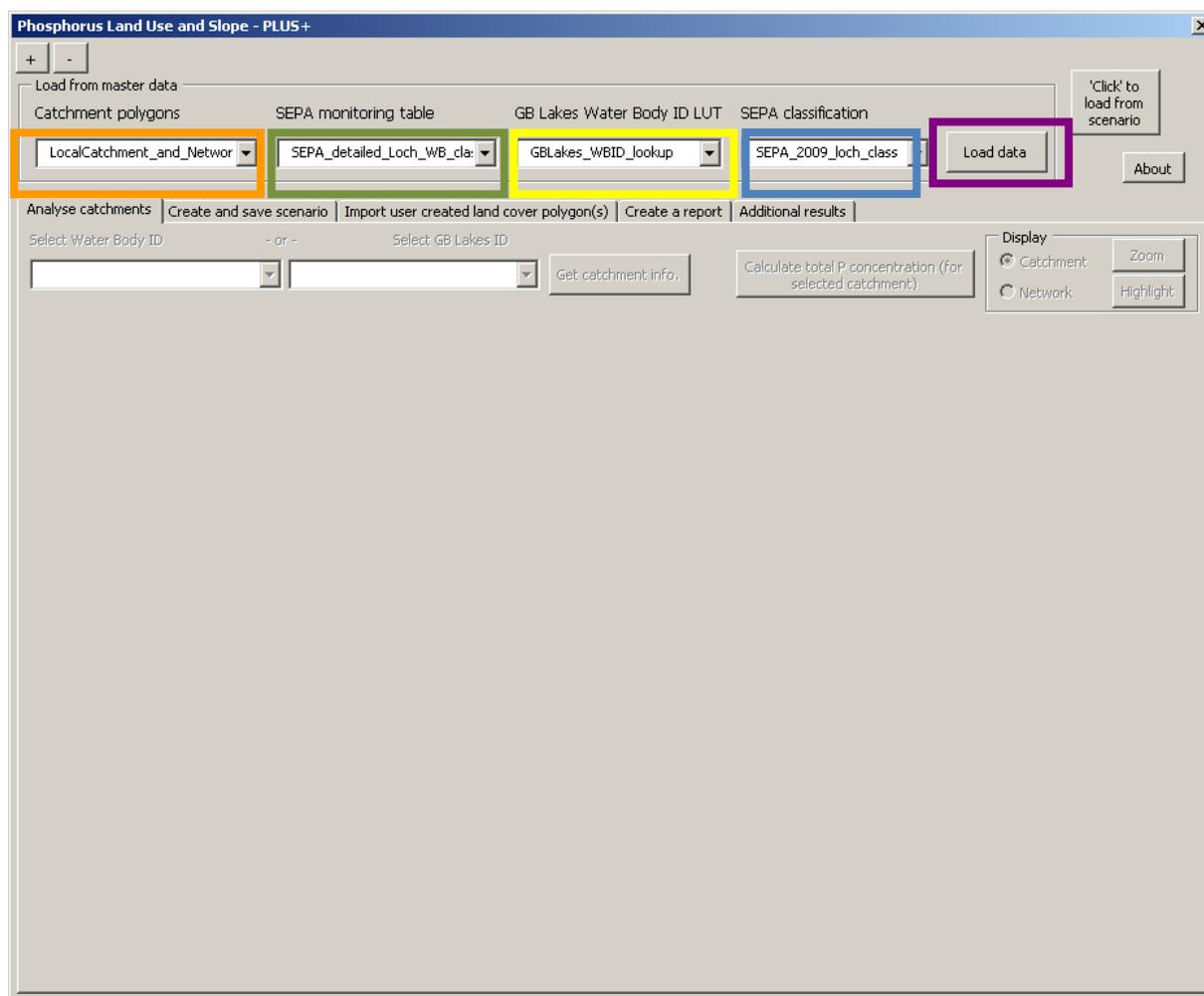
“UIToolControl1”. If this name is not used then please modify any occurrences of “UIToolControl1” that you have copied into ‘ThisDocument’ in Normal.mxt (within the VBA environment). Alternatively the application can be started within the VBA environment.

3.2 Getting started/obtaining default model output

- 1) Open ArcMap and if necessary add the contents of the two personal geodatabases: SourceData.mdb and ScenarioData.mdb. Also add the SEPA look up table to relate GB Lakes and Water Body identifiers and the SEPA loch Water Body classification table. Add Ordnance Survey or other map data if required.



- 2) If a custom button to the tool has been installed then click on it (highlighted in purple in the example above, your configuration may differ) to start the application (or start it through the VBA environment) and the following menu should appear. If at any time you close PLUS+ you will need to reopen the application – the state of the model is not stored (other than when scenarios are explicitly saved by the user to the scenario geodatabase). Selecting another tool within ArcMap will enable you to reselect the PLUS+ tool to restart the application. An additional information tool has been implemented in the source code such that if the LocalCatchment_and_Network layer is at the top of the table of contents then clicking on one of the catchments in the map window will display the GB Lakes ID and name of the catchment.
- 3) The tool has been designed so that commands and options are context sensitive – buttons become available to click only when necessary conditions in the processing flow have been met or suitable options chosen or data loaded. As can be seen below, much of the application window is empty and the buttons and options greyed-out to indicate to the user that they have been disabled. At this stage the only available processing option is to load input data (either source or scenario). Or to collapse or expand the tool (+ and – buttons in the top left corner).

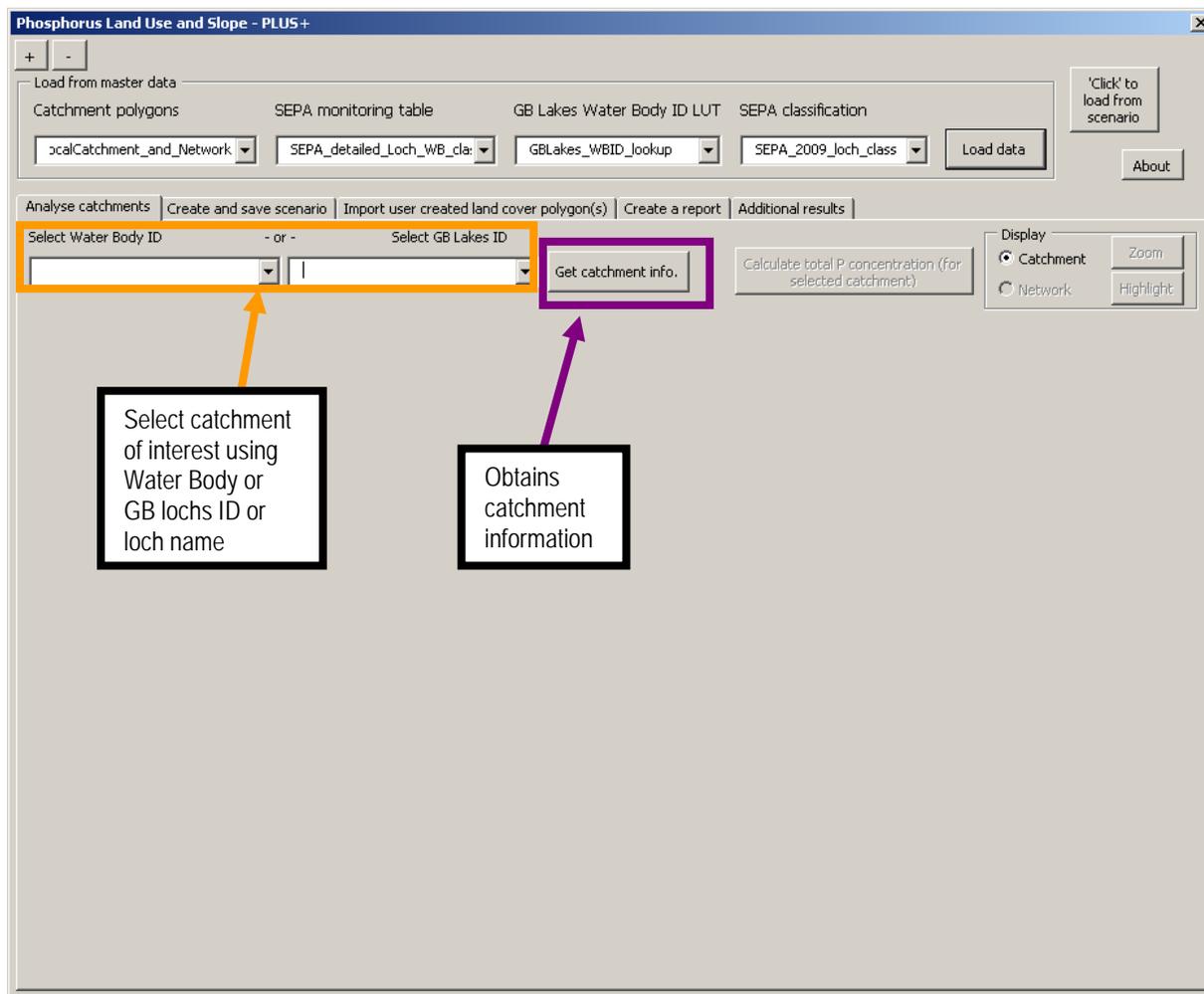


- 4) To obtain and work with information from the default PLUS+ model populate the drop down boxes as follows:
 - Catchment polygons (highlighted in orange above) : “LocalCatchment_and_Networ”, the polygon feature class containing the catchment boundaries
 - SEPA monitoring table (highlighted in green above): “SEPA_detailed_Loch_WB_classification”, geodatabase table containing High/Good etc. descriptions of water bodies and the classification year
 - GB Lakes Water Body ID LUT (highlighted in yellow above): “GBLakes_WBID_lookup”, geodatabase or standalone table with WFD_WB_ID and GB_WB_ID fields
 - SEPA classification (highlighted in blue above): “SEPA_2009_loch_class”, geodatabase or standalone table with measured P concentration and year of classification
- 5) When the four drop down boxes have been correctly configured click on “Load data” (highlighted in purple above). To work with previously saved scenario data see procedures described below.
- 6) The “Load data” button will load the layers and tables selected in the four drop down boxes in addition to the tables in SourceData.mdb (and in scenario loading also ScenarioData.mdb). The use of drop-down selection boxes allows for flexibility in input data names, however you must ensure that the data structure of alternate

source files matches those described in this manual and supplied with the PLUS+ MXD file.

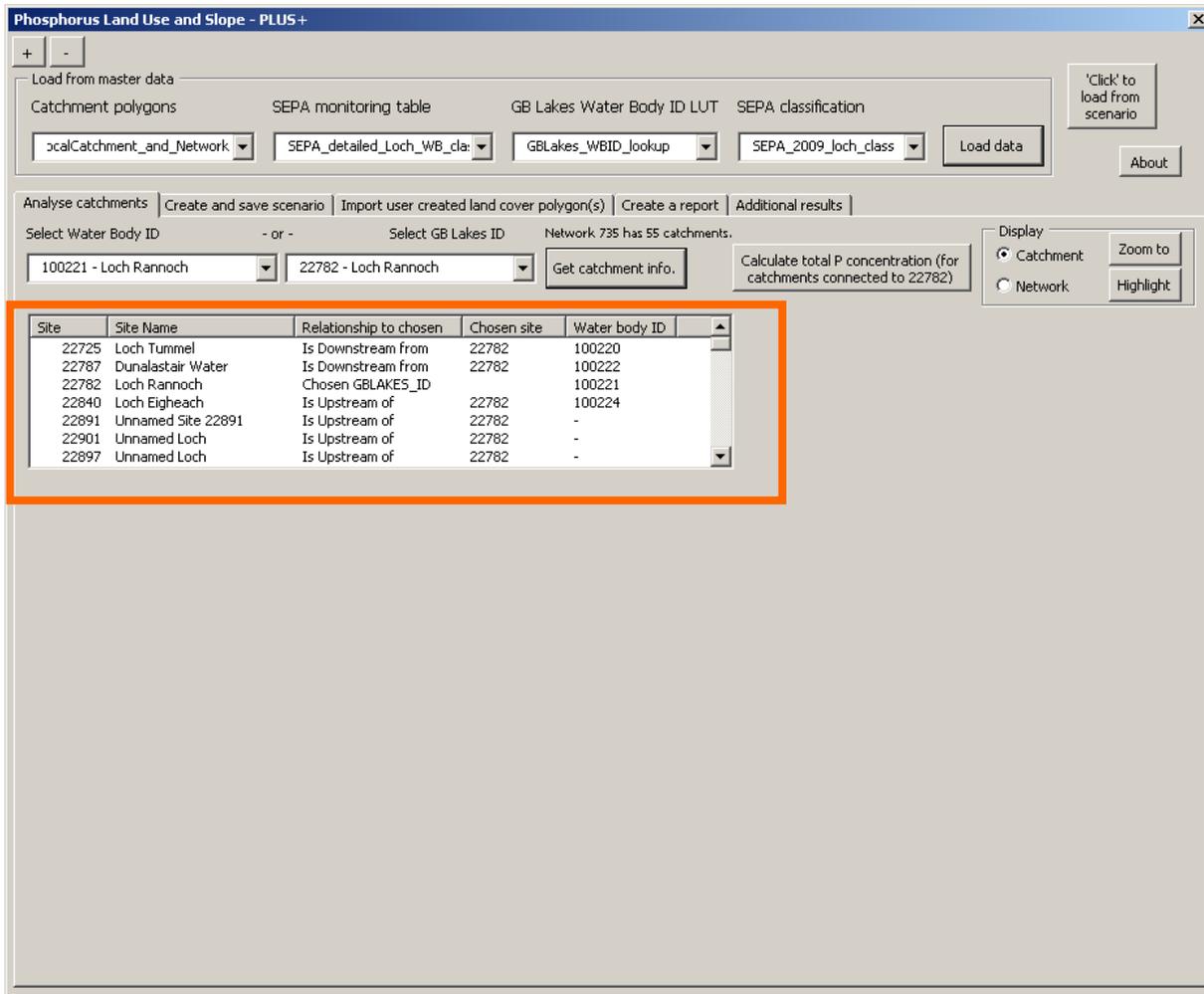
- 7) Following the clicking of “Load data” the application should appear as below. The loch of interest can be selected from the drop down boxes highlighted in orange (below) either through typing in the loch’s Water Body ID or GB loch ID or through scrolling down one of the lists (ID for Loch Lomond and Loch Awe are GB loch IDs for 24447 Loch Lomond and 24025 Loch Awe respectively [these two lochs are split in two within the GB lochs dataset]). Selecting a Water Body ID or a GB Lakes ID will automatically select the equivalent loch in the other menu if it exists in the tables used. Note that there are not Water Body IDs for every GB Lake in the data base. When PLUS+ is in use and the LocalCatchment_and_Network shapefile is displayed on the map (and uppermost in the table of contents and not in a group layer), clicking on a catchment in the map window will result in a box appearing with the associated loch’s name and ID. If the latter function is not available then use of ArcMap’s information tool will also provide this information within the “SITECODE” field of the layer “LocalCatchment_and_Network”.

Clicking on “Get catchment info.” (highlighted in purple below) will load the selected catchment’s information into the application and take the user on to the next stage of using the model.



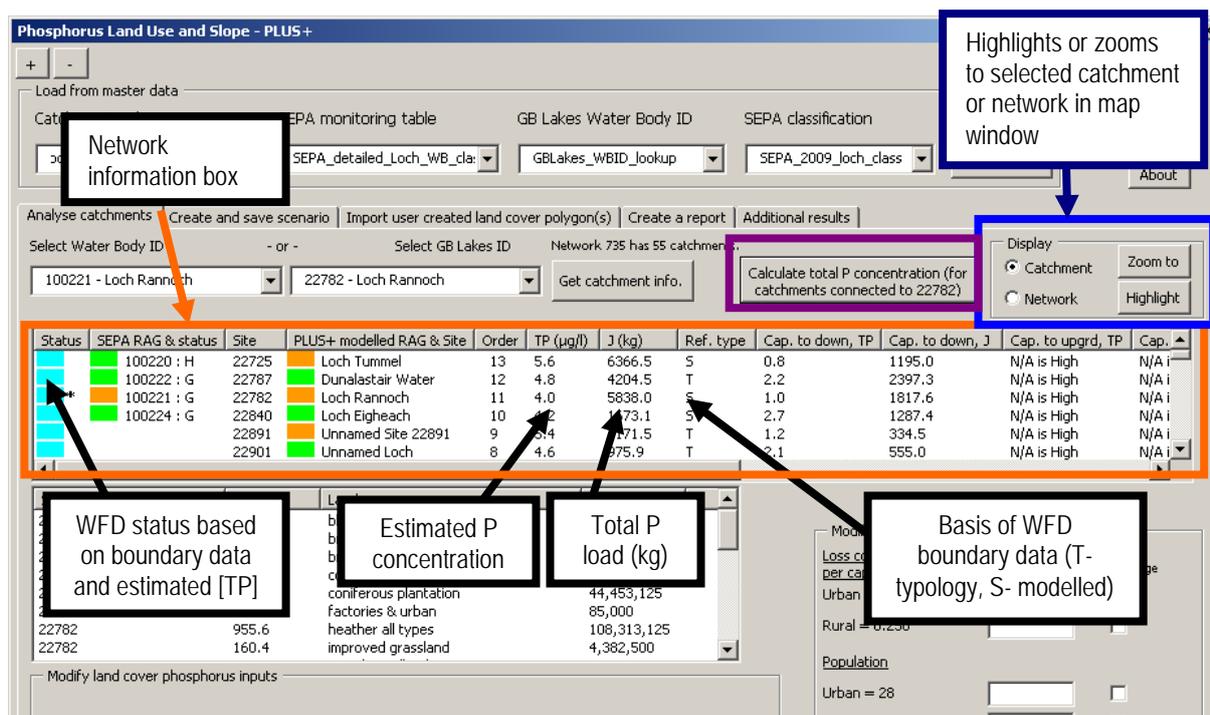
- 8) The following network information box should appear (highlighted in orange) when “Get catchment info.” has been clicked. This box highlights the GB loch and Water Body IDs (where available) of lochs either downstream from the chosen site (appear above the chosen site in the listing), those located upstream (appear below the

chosen site) as well of those situated on a separate branch of the main river catchment (i.e. within the same main river catchment but not linked to the selected catchment directly by flow).



It is now possible to zoom to or highlight the network of catchments related to the selected loch (see blue box below). If you select one of the lochs within the main scroll text list on the left this will automatically be highlighted within the map.

Clicking “Calculate total phosphorus concentration...” (highlighted in purple below) will obtain estimates of total P concentration for each catchment in the scroll down box and take the user on to the next stage of using the model.



9) The information contained within the network information box (again highlighted in orange above) will change to include the following:

- **Status** – a box will appear containing a colour representing the status of the loch calculated by comparing the estimated total P concentration to Water Framework Directive (WFD) boundary conditions (see Table 4 below for a summary of all colour options). Hovering the cursor over the individual box will provide a text description of the status. The water body which was selected by the user is highlighted by a “*”.

Table 4 Summary of status colours

	High
	Good
	Moderate
	Poor
	Bad
X	Not available (boundary data not available as loch is not a WFD water body)

- **SEPA RAG & Status** – where available the Water Body ID, the calculated Red/Amber/Green (or “RAG”) SEPA warning classification for the measured concentration, and its status (H = High etc.) from the SEPA annual assessment is given. Note that there are more than two hundred water bodies for which Water Body ID exists but for which no SEPA measurement is in the supplied data. In these cases this column will contain only the Water Body ID. A comparison is made between the status in the SEPA standalone table selected by the user and the status of the measured value compared to the break points in the TPBreakPoints table in the SourceData database. Where there is a discrepancy between these assessments both values will be given in this column in the following format:

“100320 : G, TPBreakPoints = H”.

This indicates that the SEPA monitoring table has a status of Good, but that the measured value corresponds to a status of High in the source database table. Note also that all RAG assessments compare the measured value with the status

derived from the TPBreakPoints table, and not the value in the SEPA measurement table. If the TPBreakPoints table contains inappropriate information then it should be updated manually or using the additional form tool supplied for the task (frmUpdateBreakPoints).

- **Site** – GB lakes ID of loch.
- **PLUS+ modelled RAG & Site** – the modelled Red/Amber/Green (or “RAG”) SEPA warning classification and the name given to the loch in GB lakes database. Hovering over this section will display the RAG colour as text. Refer also to the “Additional results” tab in the tool.
- **Order** – stream order of the loch (Strahler system). Hovering the cursor over the order number will reveal the relationship of the highlighted loch to the selected loch (downstream, upstream, separate branch or chosen water body).
- **TP (µg/l)** – total P concentration in µg/l within the loch estimated by PLUS+. Note that where a SEPA measured value exists in the user selected SEPA classification table for the TP this can be viewed by hovering the cursor over this field. The measurement will appear as e.g. “Meas: 7.7”, the units being the same as those of the PLUS+ calculation.
- **J (kg)** – the sum of inputs of P to the site in kg (including local catchment land cover, local catchment point sources and upstream inputs). A back-calculated estimated J for those water bodies with SEPA concentrations is included in a hover-over tooltip. Please note that these values are estimated from the SEPA concentration and include upstream and local run-off.
- **Ref. type** – identifies the reference type - whether the WFD condition boundary information is based on typology (T), on values specifically modelled for the site (S) or not available as the loch is not a WFD water body (not av.).

To avoid designing a form which occupies the whole of a user’s screen several of the remaining output columns scroll off to the right of the network information box, the figure below has been scrolled to the right to display these values. The display of capacity to upgrade and downgrade is dependent on the water body status – if the status is high then upgrade capacity is not available, if the status is poor then downgrade capacity is not available.

The screenshot shows the PLUS+ software interface. At the top, there are tabs for 'Analyse catchments', 'Create and save scenario', 'Import user created land cover polygon(s)', 'Create a report', and 'Additional results'. Below the tabs, there are input fields for 'Select Water Body ID' (100221 - Loch Rannoch) and 'Select GB Lakes ID' (22782 - Loch Rannoch). A button 'Get catchment info.' is visible. A tooltip is displayed over the 'Calculate total P concentration (for catchments connected to 22782)' button. The main area contains a table with the following data:

type	Cap. to down, TP	Cap. to down, J	Cap. to upgrd, TP	Cap. to upgrd, J	Meas.Cap. down, TP	Meas.Cap. down, J	Meas.Cap. upgrd, TP	Meas.Cap. upgrd, J
0.8	1195.0	N/A is High	N/A is High	N/A is High	2.8	3790.6	N/A is High	N/A is High
2.2	2397.3	N/A is High	N/A is High	N/A is High	2.2	2684.6	N/A is High	N/A is High
1.0	1817.6	N/A is High	N/A is High	N/A is High	0.2	445.3	N/A is High	N/A is High
2.7	1287.4	N/A is High	N/A is High	N/A is High	3.4	1695.4	N/A is High	N/A is High
1.2	334.5	N/A is High	N/A is High	N/A is High				
2.1	555.0	N/A is High	N/A is High	N/A is High				

Below this table is another table showing site data:

Site	P (kg)	Land cover	Area (m ²)
22782	131.7	blanket bog & peatland	49,229,375
22782	0.4	bracken	31,250
22782	102.0	broadleaved woodland	4,472,500
22782	97.3	coarse grassland	11,621,250
22782	581.4	coniferous plantation	44,453,125
22782	19.0	factories & urban	85,000

At the bottom right, there is a section for 'Modify point sources for 22782' with a table for 'Loss coefficient (kg P per capita)'. The 'Urban' row has a value of 0.913. There are input fields for 'Enter new values' and a 'Tick box to enable change'.

The calculated (modelled) and measured load and concentration are compared to the values in the TPBreakPoints table (or the TPBreakPoints_S table in the case of a loaded scenario being analysed). The capacity to upgrade is displayed with a negative number to remind the user that this amount must be removed from the system to effect an upgrade. These capacities are local to the water body and do not take account of downstream effects. Applying changes to a catchment will have consequential effects downstream as with the application of any additions or removals.

- **Cap. To down, TP** – the remaining capacity in calculated (modelled) concentration before the assessment is downgraded to the next lower quality status.
- **Cap. To down, J** – the remaining capacity (i.e. how much P can be added) in calculated (modelled) load before the assessment is downgraded to the next lower quality status.
- **Cap. To upgrd, TP** – the required reduction in calculated (modelled) concentration required before the assessment is upgraded to the next higher quality status.
- **Cap. To upgrd, J** – the required reduction in calculated (modelled) load required before the assessment is upgraded to the next higher quality status.
- **Meas. Cap. To down, TP** – the remaining capacity in measured concentration before the assessment is downgraded to the next lower quality status. The measured concentration is compared to the SourceData TPBreakPoints table.
- **Meas. Cap. To down, J** – the remaining capacity in measured load before the assessment is downgraded to the next lower quality status.
- **Meas. Cap. To upgrd, TP** – the required reduction in measured concentration required before the assessment is upgraded to the next higher quality status.
- **Meas. Cap. To upgrd, J** – the required reduction in measured load required before the assessment is upgraded to the next higher quality status.

An additional box of local catchment land cover information (highlighted in yellow below) will also have appeared with the results.

This box provides the following:

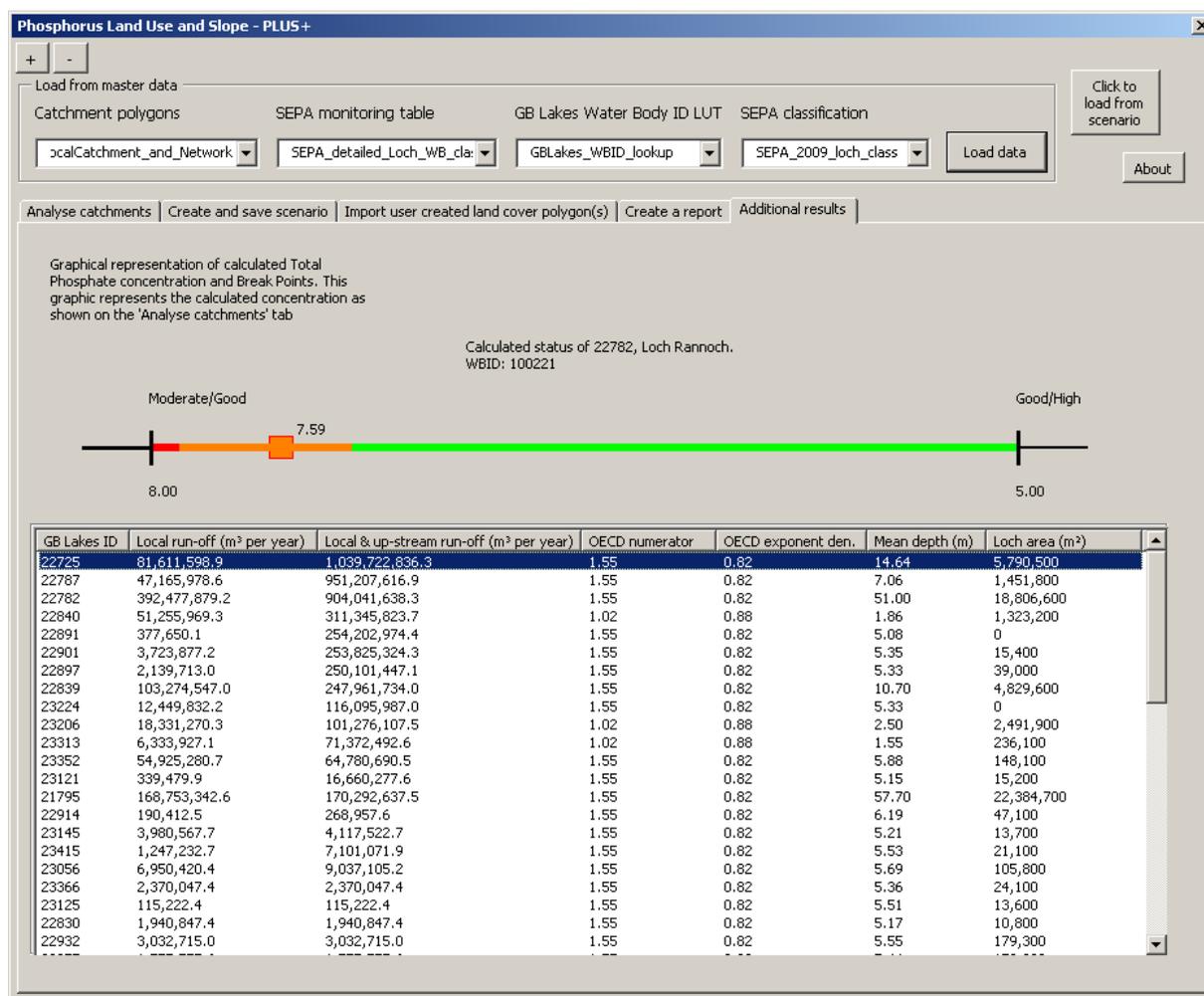
- **Site** – the GB lakes ID of the selected loch.
- **P (kg)** – total P load in kg from the relevant land cover type within the local catchment^(see NB below) (sum of the P load calculated for the different areas of that land cover within the local catchment considering slope).
- **Land cover** – land cover class taken from LCS88 data.
- **Area (m²)** – total area of LCS88 land cover type in the local catchment of the loch in m².

NB local catchment refers to the land where water drains to the loch of interest without passing through any other lochs included within the model. P from land draining to upstream lochs is routed by the model via the upstream lochs and is represented by P from upstream in “sum P” (at the bottom of the box, see below).

Scrolling to the bottom of this box (see additional yellow box below) provides the following information:

- **Sum P** – this is the modelled total P in kg coming from the local catchment land cover, local catchment point sources and from upstream (if applicable).
- **Sum land cover inputs** – the sum of P in kg modelled as coming from the land cover in the local catchment.
- **Sum upstream inputs** – modelled total P coming from the loch upstream (this will include the P from lochs further upstream).
- **Urban** – modelled P load in kg coming from urban WWTWs.
- **Urban population** – number of people classified as living in urban areas by PLUS+ (see section 2.3.2 for default assumptions).
- **Rural** – P load in kg coming from septic tanks.
- **Rural population** – number of people classified as living in rural areas by PLUS+ (see section 2.3.2 for default assumptions).

10) Further results are available in the ‘Additional results’ tab.



This section is in two parts. In the upper part there is a graphical representation of how close a calculated TP (in this case a value of 7.59) is to the nearest break point. This also shows the RAG classification within the quality assessment. In the above example the calculated TP is between Moderate/Good and Good/High. Adding or removing sources of P (and recalculating total P) while evaluating scenarios will move the red block's position relative to the break point markers. Note that in the above example a significant amount of modelled point source P has been added to the base line total P for Loch Rannoch for illustration purposes.

The lower part of this tab gives a tabular output of model parameters not available in the first tab of PLUS+. Run-off, the OECD parameters used to solve the model and the area and mean depth of the lochs used in the model solution are included.

Note that in the source data 74 out of the 8030 lochs are listed as having a value of zero for area. These 74 include the two examples 22891 & 23224 shown above. Inspection of a number of these catchments (25369, 26878, 23876, 18261, 18323, 18062) has shown that these catchments do not have a significant body of standing water, many are actually rivers. For these catchments the result of the calculation of water residence time is zero (Equation 2, above), resulting in a calculation of TP for these catchments of:

$$[TP] = aJ^b \quad , \text{ rather than } [TP] = a \left(\frac{J}{1 + \sqrt{T_w}} \right)^b$$

It must be noted that the OECD equations are only valid for lakes where annual TP load and

annual turnover control the observed TP. This approach (as adopted in PLUS+) is not appropriate for rivers as they have a different dynamic and TP is controlled by additional factors.

3.3 Modifying the default model/scenario model output

3.3.1. Land cover modifications

3.3.1.1. Bulk changes to land cover area or loss coefficient

PLUS+ allows bulk changes to local catchment land cover areas, including a check sum to ensure that the total catchment area is not unintentionally changed. The exports due to land cover are affected by the underlying slope. Altering land cover area using this bulk change removes the influence of slope. Unless the loss coefficient for the land cover is changed using the supplied function (either in the local catchment or within the entire network) PLUS+ will automatically use the loss coefficient for medium slope. To retain the influence that slope has on P export due to land cover, new land cover polygon data should be imported (see section 3.4.1.2). As just mentioned, the model also allows bulk changes to be made to the loss coefficient associated with a land cover either within the local catchment alone or the entire network associated with the catchment. Again changing the loss coefficient in this manner removes the influence on slope with a single loss coefficient being used for the land cover regardless of the slope. To make slope specific changes to the loss coefficients the baseline input data of the model must be changed.

Getting started

- 1) Obtain the default model output for the loch of interest (section 3.2) or load the relevant scenario you wish to use as a baseline (section 3.5) and obtain the model output for the loch of interest (section 3.2).
- 2) Selecting a land cover within the local catchment land cover information table (highlighted in yellow below) by clicking on the relevant row of the table will cause options to appear (highlighted in orange below) which allow bulk changes in the area (m²) of the land cover in the local catchment or P loss coefficient (kg/ha) coming from that land cover in the local catchment.

The screenshot shows the PLUS+ software interface. At the top, the site name is '22891 Unnamed Site 22891' with parameters 9, 5.4, 1170.5, and T. Below this is a table of land cover data:

Site	P (kg)	Land cover	Area (m sq.)
22782	131.9	blanket bog & peatland	49,354,999
22782	0.3	bracken	27,500
22782	101.8	broadleaved woodland	4,465,000
22782	97.5	coarse grassland	11,655,000
22782	582.3	coniferous plantation	44,535,000
22782	18.6	factories & urban	82,500
22782	958.4	heather all types	108,687,500
22782	160.3	improved grassland	4,377,500
22782	209.3	mixed woodland	12,075,000

Below the table is a configuration panel titled 'Modify land cover phosphorus inputs'. It contains several options and input fields:

- Change Area of blanket bog & peatland (kg/ha) [Input field: Enter new area (m)]
- Change P export coeff. of blanket bog & peatland [Input field: 0.027, Enter new P (kg/ha)]
- Change P export coeff. for blanket bog & peatland for whole network
- Radio buttons: Use read-in values, Use modified values
- Buttons: 'Reset modified values' (highlighted in red), 'Modify inputs (for 22782)' (highlighted in purple)

Callouts provide instructions:

- 'To apply loss coefficient change for land cover throughout network' points to the 'Change P export coeff. of blanket bog & peatland' checkbox.
- 'Bulk change to area of land cover' points to the 'Change Area of blanket bog & peatland' checkbox.
- 'Bulk change to loss coefficient for land cover' points to the 'Change P export coeff. of blanket bog & peatland' input field.
- 'Resets values to the default values of the model' points to the 'Reset modified values' button.
- 'Select before re-running model to run model with modified values or default values' points to the radio button selection.
- 'Press to re-run model' points to the 'Modify inputs (for 22782)' button.

Bulk land cover change

- 1) Select the land cover you wish to change in the local catchment land cover information table (box highlighted in yellow above), enter your new value of the area of the selected land cover and ensure that the check box to the left of “Change area of ...” is ticked (highlighted in yellow below), select the option to “Use modified values” (highlighted in orange below and disabled by default) and then click the “Modify inputs” button (highlighted in purple below). This process can be repeated for any number of land cover units, however ‘Modify inputs’ must be clicked after each modification to commit it to the model. Following your modifications information similar to that below will appear (highlighted in red, blue and green) which will allow you to modify other land cover values to ensure the total area of the catchment does not change (see step2).

Select Water Body ID: 100221 - Loch Rannoch | - or - | Select GB Lakes ID: 22782 - Loch Rannoch | Get catchment info.

Status	SEPA Status	Site	Site Name	Order	TP (µg/l)	J (kg)	Ref. type
	H	22725	Loch Tummel	13	5.6	6333.9	S
	G	22787	Dunalastair Water	12	4.8	4164.8	T
*	G	22782	Loch Rannoch	11	4.0	5762.2	S
	H	22840	Loch Eigheach	10	4.2	1672.0	S
		22891	Unnamed Site 22891	9	5.4	1170.5	T

Site	P (kg)	Land cover	Area (m sq.)
22782	53.5	blanket bog & peatland (mod.)	20,000,000
22782	0.3	bracken	27,500
22782	101.8	broadleaved woodland	4,465,000
22782	97.5	coarse grassland	11,655,000
22782	582.3	coniferous plantation	44,535,000
22782	18.6	factories & urban	82,500
22782	958.4	heather all types	108,687,500
22782	160.3	improved grassland	4,377,500
22782	209.3	mixed woodland	12,075,000

Modify land cover phosphorus inputs

Your total area is too low by 29,354,999

Resolve area difference by adjusting blanket bog & peatland

blanket bog & peatland, P = 0.027 kg/ha

blanket bog & peatland

Change Area of blanket bog & peatland | 20000000 | Enter new area (m)

Change P export coeff. of blanket bog & peatland | | Enter new P (kg/ha) ?

Change P export coeff. for blanket bog & peatland for whole network

Use read-in values

Use modified values

Reset modified values

Modify inputs (for 22782)

- PLUS+ will automatically detect when the model has been run using modified values which cause a total increase or decrease in local catchment area (highlighted in red above) and provide options to resolve this. Using the drop down box (highlighted in green above) or by clicking on a land cover type in the text window above it the user can select a land cover the area of which they wish to amend to resolve the change in catchment area, then clicking the “Resolve area difference...” button (highlighted in blue) the area difference will be resolved through changes to this one land cover. If the user wishes to resolve the difference by making changes to multiple land covers they will need to do this by repeating step 1 for multiple land cover units. Once resolved the model can be run using these new values by ensuring “Use modified values” is selected (highlighted in orange above) and pressing the “Modify inputs” button (highlighted in purple above). Should a number of changes to the amounts of different land cover be required it is recommended that the user do this through creating and saving and then loading scenarios, building up the new arrangement incrementally.
- If you wish to introduce a land cover which is not present in the base line of your selected catchment you must first reduce the area of one of the existing land covers. When this has been applied by clicking ‘Modify inputs...’ a drop-down menu will appear containing all land covers in the model for you to select one and reconcile the area discrepancy now in the model. Note that you must click the ‘Resolve area difference button’ highlighted in blue above. Clicking on ‘Modify inputs...’ will not implement this change. To subsequently modify one of the existing land covers you

should select it from the information window above and not from the drop down menu highlighted in green. The drop down menu highlighted in green should only be used to introduce new land covers not present in the base line data.

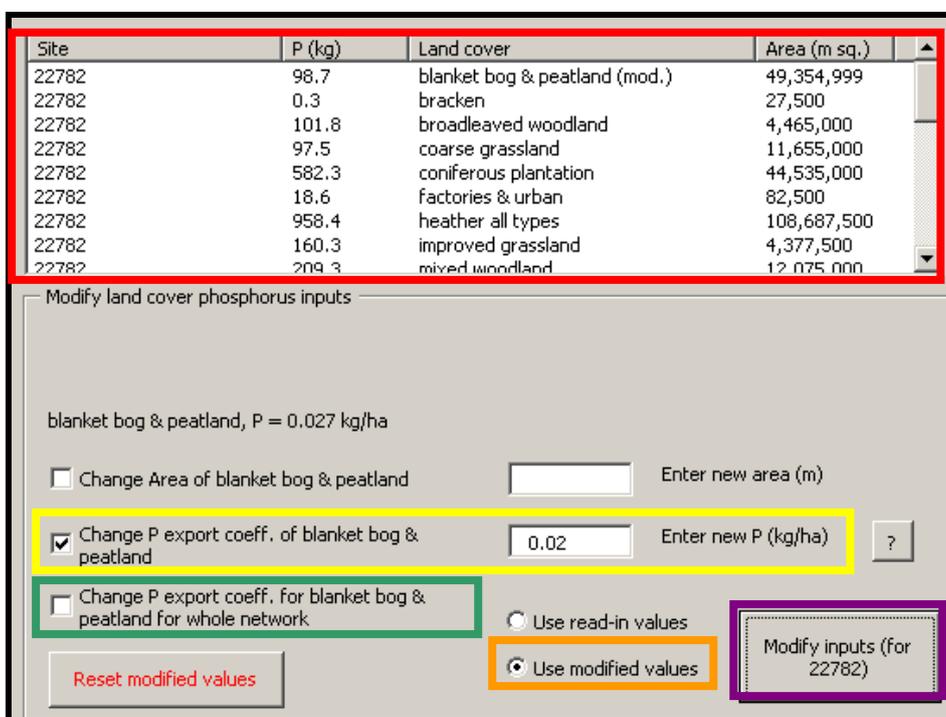
- 4) To return to the default/base line data values click on “Reset modified values”. You will be prompted to confirm this action before it is executed.
- 5) To save changes as a scenario see section 3.4.

To make bulk changes to land cover in other catchments within the network see instructions on saving scenarios and working from scenarios (section 3.5). These processes will allow a series of additional changes to be made within a network i.e. make changes to one catchment, save as a scenario, open scenario, and make changes to another catchment within the network and save a new scenario. It is not possible to make incremental changes to a number of catchments within a network without using scenario saving and loading.

Bulk loss coefficient change

- 1) Select the land cover you wish to change in the local catchment land cover information table (highlighted in red below), click on “Change P of export coeff. of ...” to select the option and enter the new coefficient value in the box in kg of P per hectare (highlighted in yellow below). If you wish to apply this loss coefficient change for that land cover type throughout the network select “Change P export coeff. for for whole network” (highlighted in green below) otherwise this change will only apply to the selected catchment (e.g. 22782 in the example below). This process can be repeated for any number of land cover types by selecting them in turn and clicking ‘Modify inputs...’ (highlighted in purple below) with “Use modified values” (highlighted in orange below) selected.

Again it should be noted this change will remove the influence of slope from the model, applying the same coefficient for that land cover type regardless of slope and that this will apply to the whole network if that checkbox is ticked.



- 2) To return to the default/base line data values click “Reset modified values”, this will undo all changes.

- 3) To save changes as a scenario see section 3.4.

3.3.1.2. New land cover data

User supplied land cover can also be used in this application. **This functionality is part of the scenario section of the application.** The user supplied land cover (which must be generated outside of the PLUS+ tool) is inserted into a subset of the land cover data corresponding to the catchment network selected by the user. If the new land cover that is to be implemented extends over more than one catchment network then the user must take account of this by processing all required networks individually. PLUS+ will only process the selected network (and will only process one network at a time, ignoring unconnected networks). Altering the land cover using this approach ensures slope is still considered by PLUS+ (assuming that slope information is provided in the user supplied data) when assigning loss coefficients.

- 1) Generate polygon of new land cover data outside of PLUS+.

PLUS+ requires that the user supplied polygon land cover data includes the following named field:

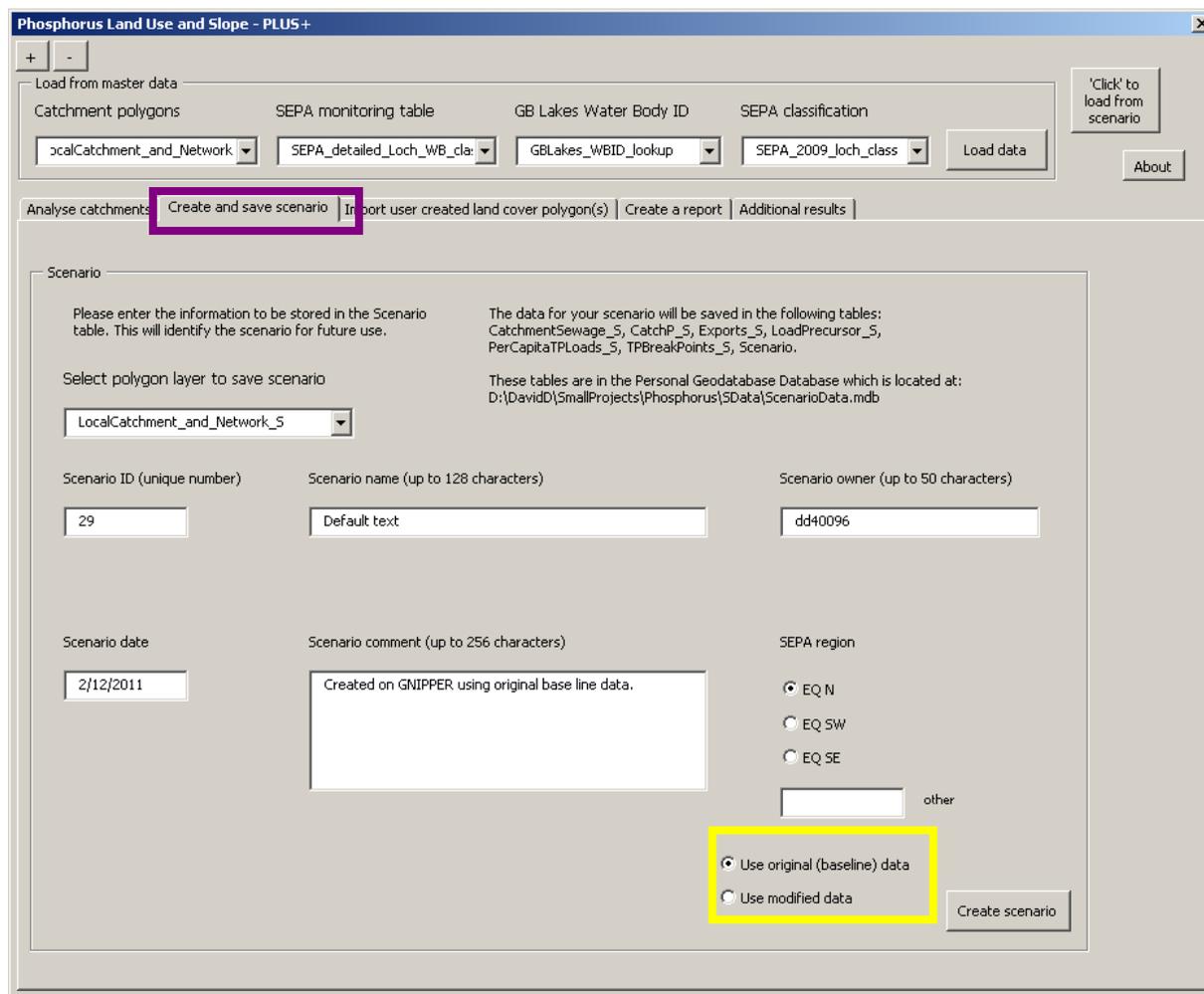
- GridCode – contains the three digit slope/land cover code (see table Exports within the geodatabase for the full list of available codes)

Below is an example of the table structure required:

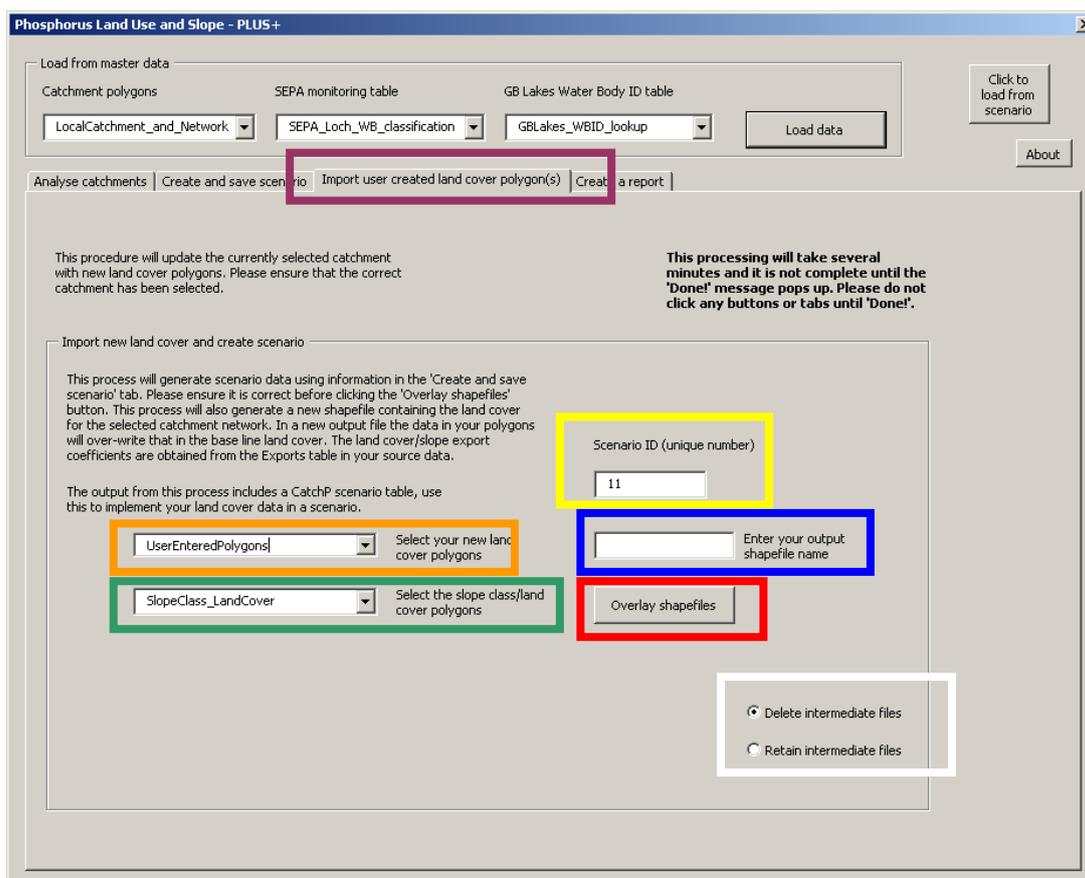
FID	Shape ^	Id	GridCode	AverageExp	Area	LCOVDESC
0	Polygon	0	108	0.123	625008.129	heather all types
1	Polygon	0	103	0.5	650862.424	blanket bog & peatland

Note that these values are hardcoded and are case and data-type sensitive. 'GridCode' must be a 'long' to ensure that the correct type of data is supplied for processing. The GridCode value is used to obtain land cover export values from the Exports table in the SourceData database (AverageExp and LCOVDESC in the above example are just for illustration and are not used). The first character in the three figure code is used to identify the slope class but is ignored in this module in favour of obtaining the slope part of the code (and subsequently the appropriate slope determined export) from the underlying base data.

- 2) Add the new polygon to the ArcMap table of contents in the normal manner.
- 3) Obtain the default model output for the site of interest in PLUS+ (section 3.3) or by loading the relevant scenario you wish to use as a baseline (section 3.5). Note that the user entered land cover polygon should at least in part overlay the network of the selected catchment. This can be checked using the highlight network function in PLUS+. As stated above the land cover update will only be undertaken for the selected network. If there are several networks of interest these will each need to be modelled individually.
- 4) To initialise the import select the "Create and save scenario" tab (highlighted in purple below) and enter the data required by the SEPA standard operating procedure for PLUS+ modelling. The scenario ID will automatically update to the next available number within the scenario database or another number may be entered by the user. **Do not click on "create scenario", in this use-case this tab is being used only to initialise the import.** Ensure that the 'Use original data' setting is selected (highlighted in yellow below). If you require to modify the land-cover coefficients it should be done after you have imported the new polygons.



- 5) Select the “Import user created land cover polygon(s)” tab (highlighted in purple below). Before using the tool please take time to read the information provided in the tab, as shown below. Within this window ensure the Scenario ID (highlighted in yellow below) matches the one assigned in the “Create and save scenario” tab (see step 4). Select the new land cover shape file created in step 1 in the drop down box highlighted in orange below, and assign a name to the resulting land cover/slope layer that will be formed in this process within the box highlighted in blue below. This output shapefile will be saved in “c:\temp”. By default the layer containing the slope class/land cover class data should automatically be selected in the drop down box highlighted in green below, however you must check that this is correct. Decide whether you would like to retain or delete the intermediate files created by the process using the option highlighted in the white box below. The intermediate files may be useful in subsequent processing.



- 6) Click the “Overlay shape files” button (highlighted in red above). This will start the computation process to develop a slope-class – land cover feature class of the overlay (intersection) of the user supplied shapefile and the base line feature class in the Scenario PGDB for the selected network. The base line data layer is very large therefore this process will take some time (possibly several minutes) even for a small catchment or small change. Once successfully processed a window with a “Done” message will pop up and the new slope class/land cover polygon will appear in the map window. Do not click any other buttons or tabs in ArcMap until the “Done” window appears or processing may be interrupted and the application may crash.

The scenario will be automatically saved in the PGDB ScenarioData.mdb using the details entered in step 4 in the “Create and save scenario” tab. Further processing of the scenario just created will use the tables in the Scenario PGDB as input data – the shapefile output will not actually be used, but is available to the user.

If the scenario ID has been used previously an error message will occur identifying that the information will not be saved. The process should be started again from step 4 using a new unique scenario ID.

This part of the application requires an ESRI function which is known to crash fairly frequently, and has no known solution. This known bug has not yet been addressed by ESRI. If an error message appears during this processing phase then ArcGIS will need to be closed and the process started again from step 2. It is likely that the user will encounter software crashes if this function of the application is used regularly. In testing during the development of this software it was found that the shutting down and then restarting ArcMap has resulted in subsequent successful execution of the overlay process. Standard GIS approaches can also be used to update the SlopeClass_LandCover feature class and the CatchP table which contains the P export for each land cover for each catchment.

- 7) To view the new model output for the network and to make further bulk changes it is necessary to load the scenario just created (refer to section 3.5).

For more extensive modifications to the land cover we would recommend editing the SlopeClass_LandCover feature class (or alternatively replacing it with an entirely new dataset) and then intersecting it with the LocalCatchment_and_Network feature class and summarising on the SITECODE attribute to produce a replacement CatchP table. **Important Note:** in PLUS+ the CatchP table in SourceData.mdb supplies the P export for each land cover in each catchment, it is vital that this is updated when the baseline land cover data set is modified.

3.3.2. Modifications to point sources

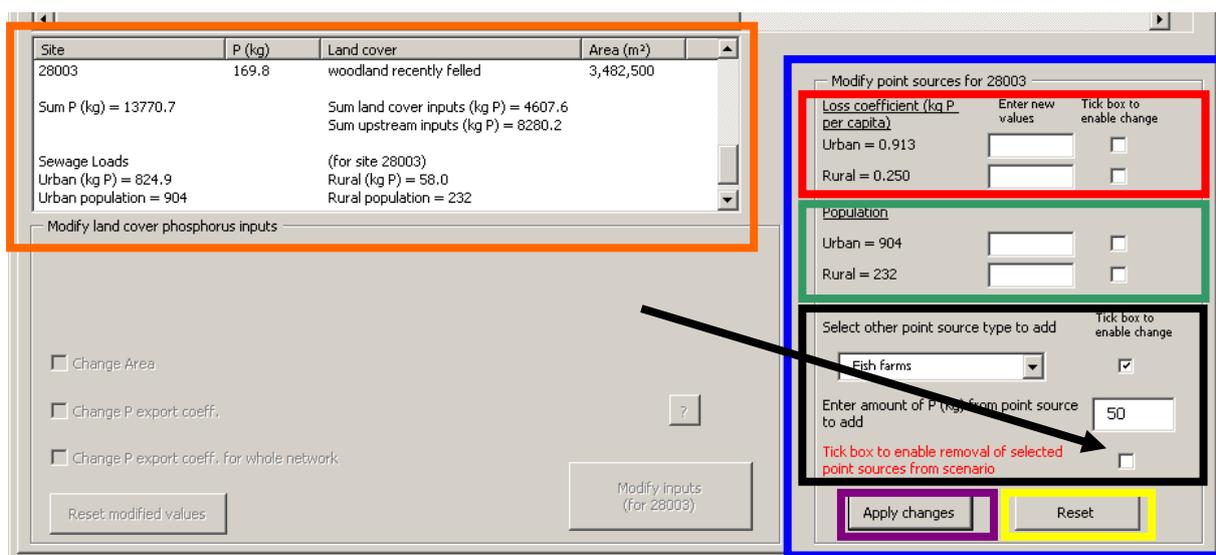
Within the model it is possible to make bulk changes (increases and decreases) to the point sources for the site of interest, including:

- The load of P entering the site per person separately for the urban and rural population.
- The total rural and/or urban population of the local catchment.
- An additional bulk P load (positive or negative) to represent other P sources or losses from the system. During the creation of a report the default text is modified when an additional point source is introduced by the user to ensure that it is recorded.

These options can be used, for example, to represent inputs from WWTWs within the local catchment servicing populations located outside of the local catchment or other specific known sources of P e.g. birds. Additionally these could be used to adjust a model run to make it more accurately reflect measured P concentrations.

3.3.2.1. Waste water treatment and other point sources

- 1) Obtain the default model output for the site of interest (section 3.3) or load the relevant scenario you wish to use as a baseline (section 3.5).
- 2) Within the “Modify point sources for...” box located in the lower right hand area of the model screen (highlighted in blue below) enter a new per capita TP load (loss coefficient) for rural/urban population (boxes highlighted in red below) and/or a new urban/rural population in the boxes (highlighted in green below). Values recorded next to each sub-heading (e.g. Urban = 0.913) are the default values.



- 3) Point sources of P can be added using the “Select other point source type to add”

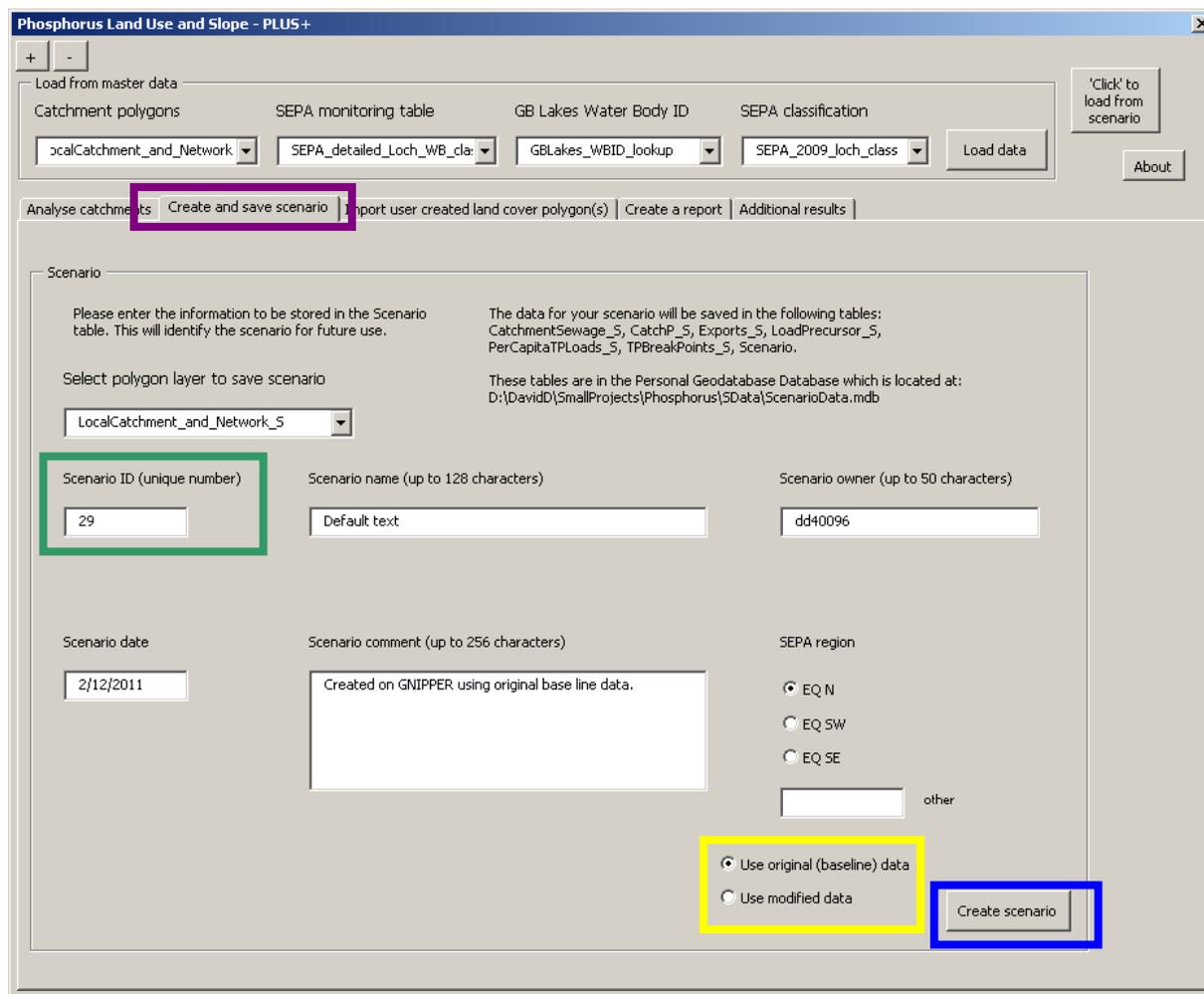
(highlighted in black above), one of the default types may be chosen or a new type typed into the window. A positive (source) or a negative (sink) value for P may be entered.

- 4) Ensuring the relevant tick boxes are selected select “Apply changes” (highlighted in purple above) and the changes will be applied to the model output in the window highlighted in orange above. Pressing “Reset” (highlighted in yellow above) will rerun the model using the default values. If a source of P is listed in the information window (in orange above) then it is used in the model. To remove an item’s source from the model you must ensure that it is removed from the information window by clicking on it in the window highlighted in orange above, and then by clicking on the tick box indicated by the black arrow above, finally click on “Apply changes” and confirm that the item you have selected has been removed. When working with a loaded scenario the “Reset” button will reload the scenario from the database.
- 5) To save changes as a scenario see the next section.

3.4 Saving changes to default as scenarios

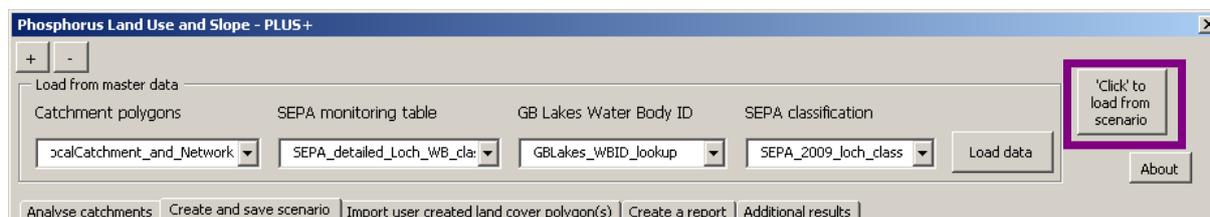
Once the default model or a scenario has been built or modified using the steps outlined above in section 3.3 it is possible to save the changes to the relevant network as a new scenario using the steps described below. This feature of PLUS+ allows the changes and results to be revisited and for subsequent changes to be made, for example further changes to other catchments within the network can be made. For instructions on how to load previously saved scenario data see section 3.5. To make multiple changes within a network (apart from in the case of loading a new land cover data set or implementing the same bulk change to land cover coefficients) it is necessary to work on one local catchment at a time through working on and saving a series of scenarios. After a scenario has been saved and reloaded any catchment within the saved network is available for further incremental scenario development. The information will be saved in the personal geodatabase ScenarioData.mdb.

- 1) Once you have made and are satisfied with your changes to the default model/scenario (see section 3.3) select the “Create and save scenario” tab (highlighted in purple below) and enter the data required by the SEPA standard operating procedure for PLUS+ modelling. The scenario ID (highlighted in green below) should have automatically updated to the next available number within the “Scenario” table in the scenario database. The Scenario owner field will be automatically populated with the logged in user’s identifier. By default the Scenario comment field will refer to the name of the computer being used. Ensuring “Use modified data” is selected (highlighted in yellow below) select “Create scenario” (highlighted in blue below). The “Use original data” option is provided to allow the saving of baseline data into a scenario. Under this option the application will always revert to the baseline (i.e. non-scenario and unmodified) data, even if scenario data has been loaded and processed. The user is given a warning message if this option is chosen within a scenario processing session.



3.5 Working with previously saved scenarios

- 1) To open a previously saved scenario select the “Click to load from scenario” button (highlighted in purple below) located in the top right hand corner of the model tool at any point.



- 2) A number of options will appear to aid the selection of the required scenario (highlighted in blue below). The scenario will be loaded based on the ID in the scenario ID box (highlighted in green below). To reduce the scenario ID list the list can be filtered using:

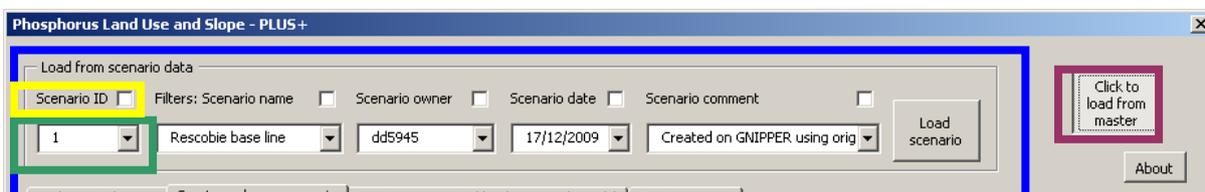
- Scenario name.
- Scenario owner.
- Scenario date.
- Scenario comment.

The desired filtering criteria can be selected from the relevant drop down box and the tick box associated with the filter selected to apply it. The information in these filters is

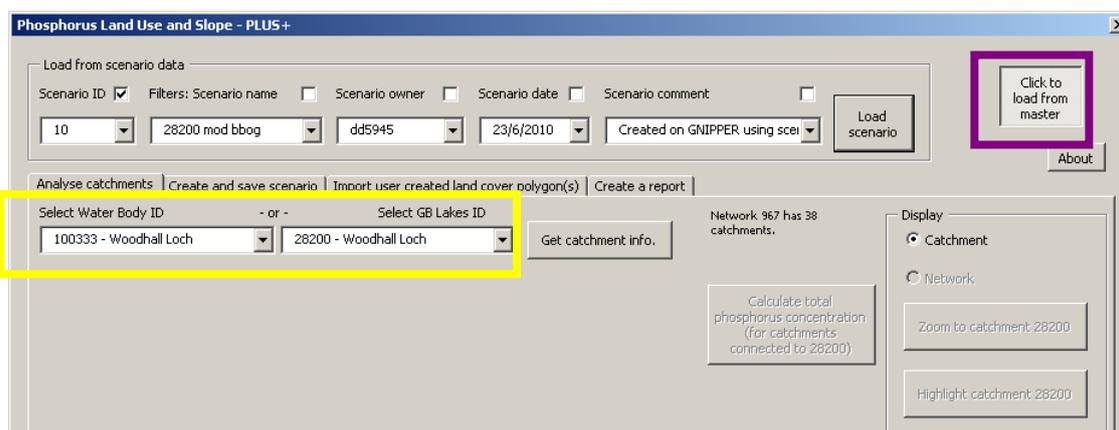
the information entered and saved when creating earlier scenarios (Section 3.5).

To view the filter information associated with a particular ID select the appropriate ID in the drop down list and then select the Scenario ID tick box (highlighted in yellow below).

To load the scenario select “Load scenario” (highlighted in purple below).



- 3) As in a default model workflow (section 3.3) the following should appear. The only difference is that the list of sites for selection (highlighted in yellow below) has been reduced to only include those catchments in the network for which the scenario was created. This data can be explored using the steps in section 3.3, further modified using the steps in section 3.4 and saved as an additional scenario using the steps described above.

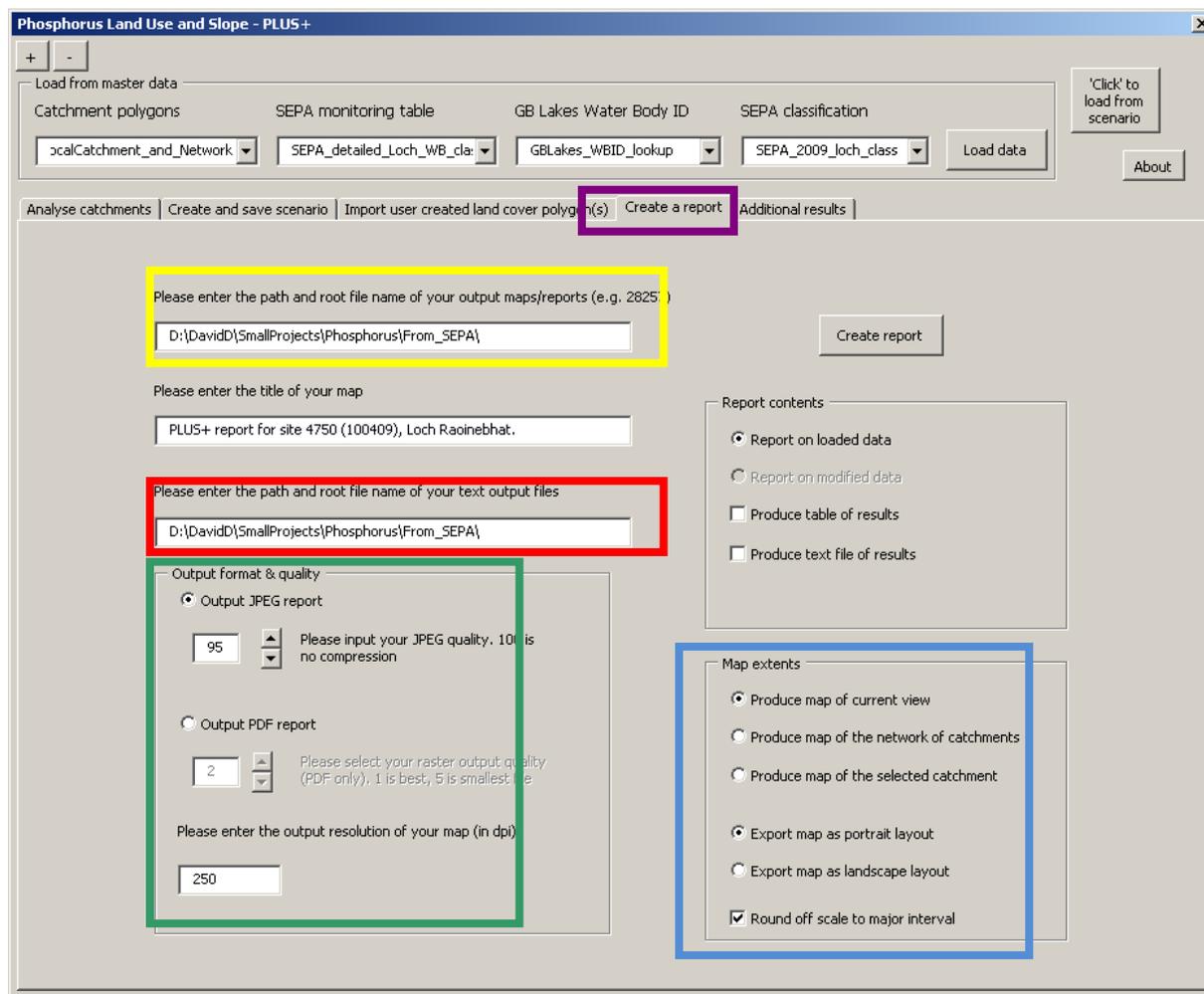


Note you can return to using the default data at any point though selecting “Click to load from master” (highlighted in purple above) and following the steps outlined in section 3.3.

The tables loaded by clicking the ‘Load scenario’ button can also be edited manually. For example the OECD denominator values could be manually edited from the standard values of 1.55 and 0.82 (for lochs of a mean depth $\geq 3\text{m}$). The values stored in the various scenario tables are loaded with the scenario.

3.6 Report writing

- 1) Once you have made and are satisfied with the required changes to the default model or scenario, or simply to report on the base-line model, select the “Create a report” tab (highlighted in purple below) and enter the options required by the SEPA standard operating procedure for PLUS+ modelling.



To prevent erroneous reporting the 'Create report' button only becomes available when the 'Calculate total phosphorus concentration' button in the 'Analyse catchments' tab has been clicked.

When any user modifiable loads are changed with the 'Modify land cover' sections or the 'Modify point sources' section the 'Report contents' box in the 'Create a report' tab is modified to disable the 'Report on loaded data' option. When modifications have been applied to the base line data within the application (outwith scenario loading and saving) the output is automatically adjusted to include the modifications and base line saving is disabled. Clicking to 'Load data', or 'Reset modified values' resets the user's modifications and gives access to base line reporting.

Using the path and root filename entered in the output window (the file output path defaults to the location of the MXD file currently in use, highlighted in yellow, above) the application will generate JPEG or PDF outputs (determined by the option box in green, above). These outputs consist of the following:

- a map of the catchment or network (determined above, blue box)
- a table of the various lochs in the network, their PLUS calculated values, modelled and measured status
- land cover statistics of the chosen loch, including P, area and percentage of catchment of each land cover
- modelled capacity to upgrade and downgrade status
- measured capacity to upgrade and downgrade status

- a summary of the PLUS calculation.

As noted above, PLUS+ will detect any discrepancy between the SEPA reported quality status and that derived from a comparison with the TPBreakpoints table. In addition to displaying this discrepancy in the main network information window the discrepancies will be written to a text output file using the root file name entered in the window highlighted in yellow above with the suffix “_StatusDiscrepancy.txt”. This file will be created for all options in the report creation tab.

If land cover statistics (and any incremental scenario modifications) of all lochs in a network are required the user must step through each catchment in turn, calculating the total P concentration and creating separate reports.

The quality of the PDF and JPEG outputs can be controlled to produce a high quality plot for printing or a lower quality plot suitable for electronic distribution (see green box above).

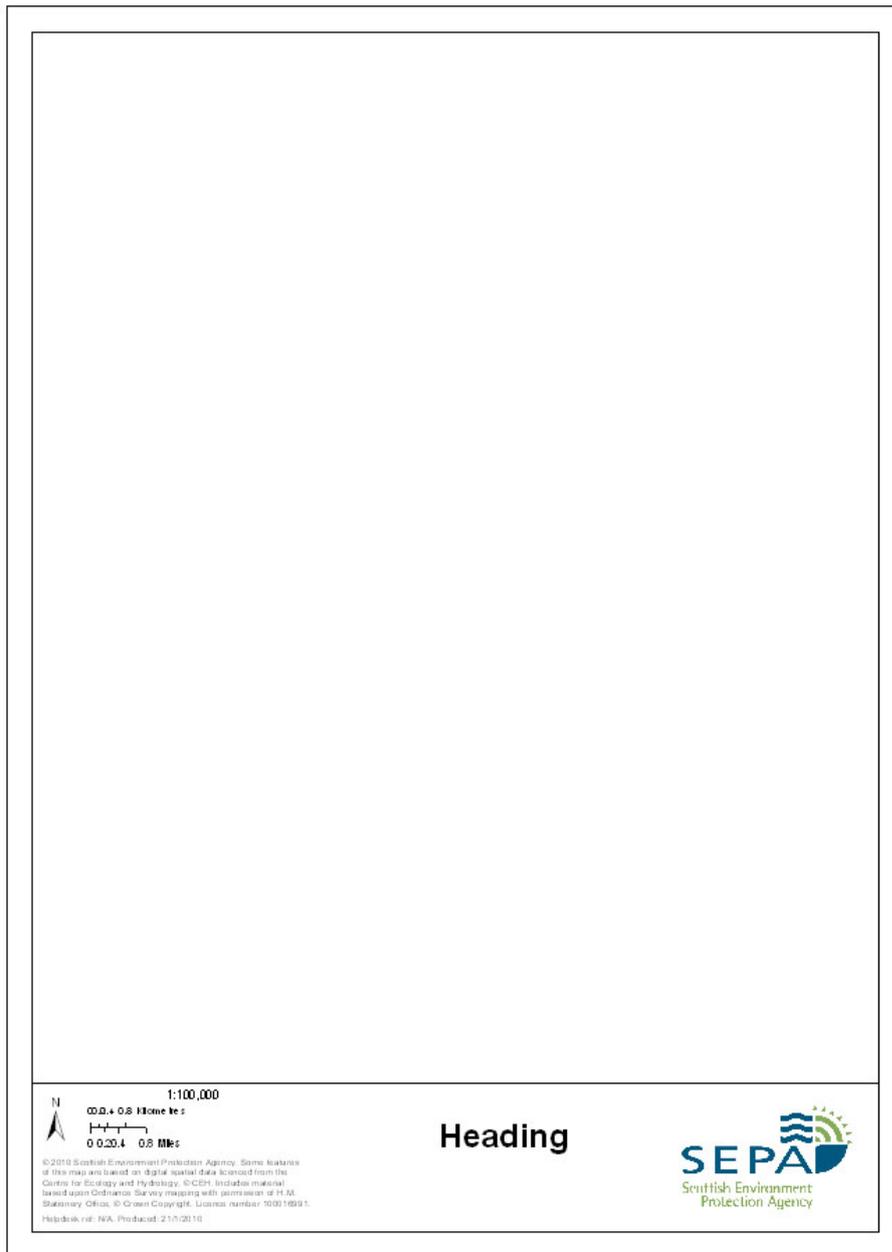
The PLUS+ application also generates comma separated text files of the above outputs from the calculations using the path and root file name entered in the window (red box, above). These text files are suitable for loading into Excel or ArcGIS as a table.

Creation of the reports will take from a few moments to several minutes to complete depending on computer speed, the number of catchments in the network and the number of land cover types in the selected catchment. PLUS+ will generate a report on the measured P concentration of the selected network of catchments. This will calculate an estimated total P load based on the measured P concentration and the local and upstream run-off. It must be emphasised that this is an estimated load.

The application relies on the graphical elements (title, scale bar etc.) in the SEPA supplied map template SEPA_A4.mxd (see below). If any of the elements in the template are modified or an alternate MXD file is used it is highly likely that the layout of the output maps will be affected detrimentally.

Please note that the creation of the JPEG and PDF reports requires PLUS+ to create table elements from lines and takes a considerable amount of processing. Networks consisting of more than a few catchments will take several minutes to process. Interrupting this processing will leave partially complete tables in the map layout of the MXD file and is very strongly discouraged.

In addition to the creation of map and tabular reports comma separated value (CSV) files of the results of the modelling are created. These files include all the information described above and are suitable for importing to Excel or other system. In each file the first line describes the structure of the data. This is described in detail in Appendix C.



Please note the following:

- The date of SEPA status in the summary P report is taken from the first record of the “CLASSIFICATION_YEAR” field in the SEPA_Loch_WB_classification table.

APPENDICES

Appendix A. Code to implement the model with ArcGIS

```
Private Sub UIToolControl1_Select()
```

```
    frmCatch.Show
```

```
End Sub
```

```
Private Sub UIToolControl1_MouseDown(ByVal Button As Long, ByVal Shift As Long, ByVal X As Long, ByVal Y As Long)
```

```
    Dim pMxDoc As IMxDocument
```

```
    Dim pActiveView As IActiveView
```

```
    Dim pPoint As IPoint
```

```
    Dim pFeature As IFeature
```

```
    Set pMxDoc = Application.Document
```

```
    Set pActiveView = pMxDoc.FocusMap
```

```
    'Create a search point
```

```
    Set pPoint = pActiveView.ScreenDisplay.DisplayTransformation.ToMapPoint(X, Y)
```

```
    'Pass the point to the FindFeature function along with the Map and search tolerance
```

```
    Set pFeature = FindFeature(pMxDoc.SearchTolerance, pPoint, pMxDoc.FocusMap)
```

```
    'Message box the feature ID and feature class alias name
```

```
    If Not pFeature Is Nothing Then
```

```
        If pFeature.Fields.FindField("SITECODE") <> -1 Then
```

```
            MsgBox pFeature.Value(pFeature.Fields.FindField("SITECODE")) & " - " &
```

```
pFeature.Value(pFeature.Fields.FindField("SiteName")), vbOKOnly
```

```
        End If
```

```
    End If
```

```
End Sub
```

```
Private Function FindFeature(SearchTol As Double, pPoint As IPoint, pMap As IMap) As IFeature
```

```
    Dim pEnvelope As IEnvelope
```

```
    Dim pSpatialFilter As ISpatialFilter
```

```
    Dim pEnumLayer As IEnumLayer
```

```
    Dim pFeatureLayer As IFeatureLayer
```

```
    Dim pFeatureClass As IFeatureClass
```

```
    Dim pFeatureCursor As IFeatureCursor
```

```
    Dim pFeature As IFeature
```

```
    Dim pUID As New UID
```

```
    Dim ShapeFieldName As String
```

```
    If pMap.LayerCount = 0 Then Exit Function
```

'Expand the points envelope to give better search results

Set pEnvelope = pPoint.Envelope

pEnvelope.Expand SearchTol, SearchTol, False

'Create a new spatial filter and use the new envelope as the geometry

Set pSpatialFilter = New SpatialFilter

Set pSpatialFilter.Geometry = pEnvelope

pSpatialFilter.SpatialRel = esriSpatialRelIntersects

'Search each selectable feature layer for a feature

'Return the first feature found

pUID = "{40A9E885-5533-11D0-98BE-00805F7CED21}" IFeatureLayer

Set pEnumLayer = pMap.Layers(pUID, False)

pEnumLayer.Reset

Set pFeatureLayer = pEnumLayer.Next

Do While Not pFeatureLayer Is Nothing

 'Only search the selectable layers

 If pFeatureLayer.Selectable Then

 ShapeFieldName = pFeatureLayer.FeatureClass.ShapeFieldName

 Set pSpatialFilter.OutputSpatialReference(ShapeFieldName) = pMap.SpatialReference

 pSpatialFilter.GeometryField = pFeatureLayer.FeatureClass.ShapeFieldName

 Set pFeatureClass = pFeatureLayer.FeatureClass

 Set pFeatureCursor = pFeatureClass.Search(pSpatialFilter, False) 'Do the search

 Set pFeature = pFeatureCursor.NextFeature 'Get the first feature

 If Not pFeature Is Nothing Then

 Set FindFeature = pFeature 'Exit if feature is valid

 Exit Do

 End If

 End If

 Set pFeatureLayer = pEnumLayer.Next

Loop

End Function

Appendix B. Application code and notes

Notes and commentary are provided within the code for the benefit of developers and support staff.

Within the “Activate” routine of the code the tables are hardcoded as follows:

```
strTblCatchmentSewageName = "CatchmentSewage"  
strTblCatchPName = "CatchP"  
strTblExportsName = "Exports"  
strTblFlowRouting = "FlowRouting"  
strTblLoadPrecursorName = "LoadPrecursor"  
strTblPerCapitaTPLoadsName = "PerCapitaTPLoads"  
strShapefileSlopeClass_LandCover = "SlopeClass_LandCover"  
strTblTPBreakPointsName = "TPBreakPoints"  
strFieldGRIDCODE = "GridCode"  
strFieldAverageExport = "AverageExp"
```

'initialise the Scenario names

```
strScenarioLocalCatchmentAndNetwork = "LocalCatchment_and_Network_S"  
strScenarioTblCatchmentSewageName = "CatchmentSewage_S"  
strScenarioTblCatchPName = "CatchP_S"  
strScenarioTblExportsName = "Exports_S"  
strScenarioTblLoadPrecursorName = "LoadPrecursor_S"  
strScenarioTblPerCapitaTPLoadsName = "PerCapitaTPLoads_S"  
strScenarioTblTPBreakPointsName = "TPBreakPoints_S"  
strScenarioTbl = "Scenario"  
strScenarioTblPointSource = "PointSource_S"
```

Should alternate table names be required then they should be edited in the “Activate” section of the VBA code – e.g. “CatchmentSewage” could be modified to “NewCatchmentSewage”. Alternatively the name in the table of contents of a replacement table could be altered to ensure that the original configuration is maintained – the actual table name is not relevant as it is the name shown in the table of contents that is used to access the table.

The configuration for the loading of SEPA monitoring data is stored in the sub-routines LoadSepaMonitoringIntoArray() and LoadSepaClassConcStat() using the ArcObjects

FindField method. If the field names to be used are different to those coded then lines of code such as:

```
pSEPAmonitoringArray(lonCounter, 0) = pRow.Value(pSEPAmonitoringTable.Table.FindField("WATER_BODY_ID"))
```

can be manually edited (changing "WATER_BODY_ID"). An accompanying test line such as:

```
intField = pSEPAmonitoringTable.Table.FindField("WATER_BODY_ID")
```

in the same sub-routine must also be edited to contain the changed field name.

Separate file (10,000+ lines of code). VBA forms are embedded in attached zip file which should be unzipped and imported into the VBA project of your MXD file as described above.



PLUS_2014.05.02.zip

Appendix C. Text output file structure

The naming of the text files follows a structure “root”_”suffix”, where “root” is a user entered name and “suffix” is supplied by PLUS+ and includes “Summary”, “CatchP” etc. In the listing below only “suffix” is shown.

Summary

ID	GB Lakes ID
WBID	Water body ID
SumP	Sum P loads (kg)
SumLCover	Sum land cover input (kg)
SumUpstream	Sum upstream input (kg)
UrbanPop	Urban population (number)
UrbanP	Load due to urban population (kg)
RuralPop	Rural population (number)
RuralP	Load due to rural population (kg)

CatchP

ID	GB Lakes ID
WBID	Water body ID
SiteName	Name of water body
ModelledStatus	Modelled P status (High etc.)
SEPAStatus	Status in user selected SEPA classification table
Order	Strahler order
ModelledTP	Modelled total phosphorus concentration (microgram per litre)
J	Modelled total phosphorus load per year (kg/year)
MeasTP	Measured total phosphorus concentration (microgram per litre) from user selected SEPA classification table
DerivedJ	Derived estimated total phosphorus load per year (kg/year), back calculated from MeasTP
RefType	Reference type (see Section 3.2.9 above)

PointSource

ID	GB Lakes ID
WBID	Water body ID
PointSource	Description of point source
Amount	P due to point source (kg)

LandCoverP

ID	GB Lakes ID
WBID	Water body ID
P	Load due to specified land cover per year (kg)
LandCover	Type of land cover
Area	Area of land cover in catchment (m)

Capacity

ID	GB Lakes ID
WBID	Water body ID
SiteName	Name of water body
ModelledTP	Modelled total phosphorus concentration (microgram per litre)
J	Modelled total phosphorus load per year (kg/year)
MeasTP	Measured total phosphorus concentration (microgram per litre) from user selected SEPA classification table
DerivedJ	Derived estimated total phosphorus load per year (kg/year), back calculated from MeasTP
TP Mod.Cap.to downgrade	Total P concentration, modelled capacity to downgrade (microgram per litre)
J Mod.Cap.to downgrade	Total P load, modelled capacity to downgrade (kg/year)
TP Mod.Cap.to upgrade	Total P concentration, modelled capacity to upgrade (microgram per litre)
J Mod.Cap.to upgrade	Total P load, modelled capacity to downgrade (kg/year)
TP Meas.Cap.to downgrade	Total P concentration, measured capacity to downgrade (microgram per litre)
J Meas.Cap.to downgrade	Total P load, measured capacity to downgrade (kg/year)
TP Meas.Cap.to upgrade	Total P concentration, measured capacity to upgrade
J Meas.Cap.to upgrade	Total P load, measured capacity to downgrade (kg/year)

CatchRelationships

ID	GB Lakes ID
WBID	Water body ID
SiteName	Name of water body
Relationship	Relationship between catchment and the chosen catchment (e.g. "Is Upstream")
ChosenSite	The GB Lakes ID.

Appendix D. Migration to ArcGIS 10.2

Note that when I most recently updated my PC to 10.2 the only adjustment required was to tick the “Microsoft Windows Common Controls 6.0 (SP6)” box.

Following the installation of ArcGIS 10.2 you must:

1. Install the ArcGIS 10.2 VBA Compatibility application.
2. Open ArcGIS
3. Under the ArcGIS “Customise” pull down open VBA Macros -> Visual Basic Editor to view the Microsoft VBA environment.
4. Under Tools -> References ensure that “Microsoft Forms 2.0 Object Library” and “Microsoft Windows Common Controls 6.0 (SP6)” are ticked. If these are not available refer to the instructions above concerning mscomctl.ocx



frmCatch_10.2.frx



frmCatch_10.2.frm

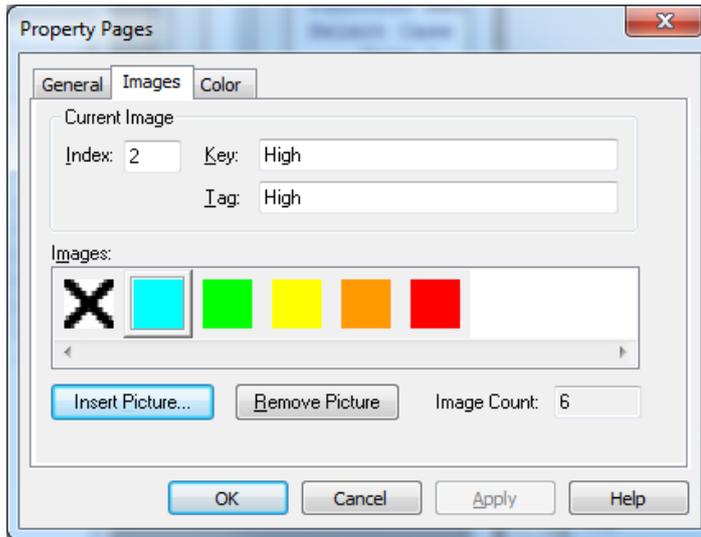
5. Import the form frmCatch_10.2.frm.
6. If the program runs but does not display the HGMPB colour icons then you will need to modify the ImageList as described below in section 15.
7. If you initially see the message window “Could not load some objects because they are not available on this machine.” Then follow these instructions:
8. Exit ArcMap.

In the folder *C:\Documents and Settings\“UserName”\Application Data\Microsoft\Forms* delete the contents, these will be recreated as needed.

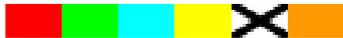
If the errors “Could not load some objects because they are not available on this machine” and “Could not load an object because it is not available on this machine” persist then it could be easier to replicate the missing items from another installation – this only takes a couple of minutes.

9. Import a copy of the form, if this does not load all the parts so they need to be manually added, this only takes a few seconds.
10. Open the form (View Object) and click on it. This should display the Toolbox of objects that can be added to the form. If it doesn't click View -> Toolbox
11. Right click on the toolbox and choose “Additional Controls” – the missing parts are not part of the standard installation of VBA.
12. Find and select “Microsoft ImageList Control 6.0 (SP4)” and “Microsoft ListView Control 6.0 (SP4)”
13. Manually add the three missing ListViews (“lvwCatchmentInfo”, “lvwCatchmentRelationships1”, “lvwCatchmentRelationships2”) to the front tab and copy only the names, size and position from the values in a working copy running in ArcGIS 10.1.
 - a. lvwCatchmentInfo – left: 6, top: 102, height: 0, width: 409.5
 - b. lvwCatchmentRelationships1 – left: 6, top: 150, height: 0, width: 409.5
 - c. lvwCatchmentRelationships2 – left: 6, top: 159.75, height: 0, width: 669.75

14. Do the same for the ListView in tab 4 ("ListViewSupplement") – all the other settings and attributes are created at runtime. This must go inside the frame in the lower half of the window of the "Additional results" tab.
 - d. lvwCatchmentInfo – left: 0, top: 0, height: 252, width: 657.75
15. Create the ImageList ("ImageList_Catchment"), this can be placed anywhere in the first tab as it is not displayed. Populate it with the images as required (HGMPB), making sure to populate the Key and Tag fields. The settings are changed by clicking on the "(Custom)" option of the ImageList and then the ... button, this will display a dialog as below. The custom size is ht=12, w=21.



The images below can be inserted.



Saving and re-importing this modified copy should present no further problems.