

VOLUME II A

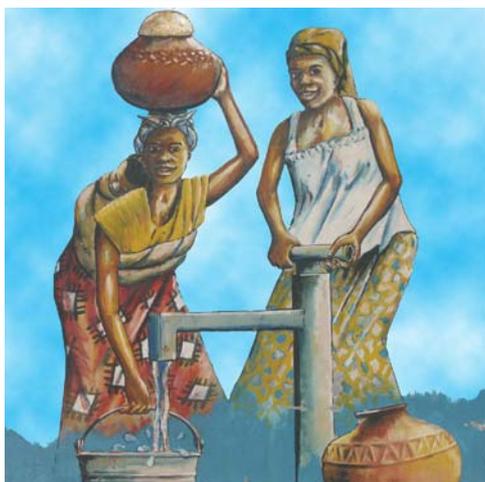
Water Resources
Database Operations
Manual



CANADIAN INTERNATIONAL
DEVELOPMENT AGENCY



FINAL TECHNICAL REPORT Hydrogeological Assessment of the Northern Regions of Ghana Project (HAP)



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1. INPUT

1.1 Data preparation for the WRC groundwater database integration

To integrate a new source of spatial data to an existent database, data must be structured to fit with the *ArcHydro Groundwater* model and set in the same coordinate system to get a perfect overlay. The projection could not be the same, the datum could be different, or in the worst case, and unfortunately it is usually this case, coordinate's information is unknown and must be assume.

1.1.1 Understanding data to integrate

The first thing to do is to understand what kind of data has to be integrated and where it will be input in the WRC groundwater data model. There are two kinds of data: data that represent objects to localise (e.g. well, aquifer, etc.) and data that represent characteristics of those objects (e.g. series, etc.). These data will be link to an object later and localised using the object coordinates.

If the data represent objects to localise, it is important to determine its spatial information. Usually, when coordinates are in degrees, they are not projected and we assume that the coordinates system is in **WGS 1984** (*classified in Geographic Coordinate Systems – World*. See the point 3.1 for details about setting coordinate system). If coordinates are in meters, the projection could be **Universal Transvers Mercator (UTM)** with different datum (*classified in Projected Coordinate Systems – UTM*), or **Ghana Meter Grid** and **Accra Ghana Grid** with the datum **WGS 1984** or **Leigon** (both classified in *Projected Coordinate Systems – National Grids*). If coordinates are in feet, the datum could be **Clarke 1866** (British war office). The point 2.2.1 below presents a method to verify a projection-datum combination for a set of coordinates.

Those projection-datum combinations has been found in the integration process but the list is not exhaustive.

If coordinates are in degrees, it is also very important to check if they are in degrees-minutes-seconds and if so, they have to be converted in decimal degrees.

After analysis, if the coordinate system is the same as the main database, next points are not necessary and the user can jump to *1.2 Input data to the WRC groundwater database*.

1.1.2 Prepare data for integration

Data to input could be digital or not. If data is already in a digital format, the information only has to be cleaned and structured before its integration.

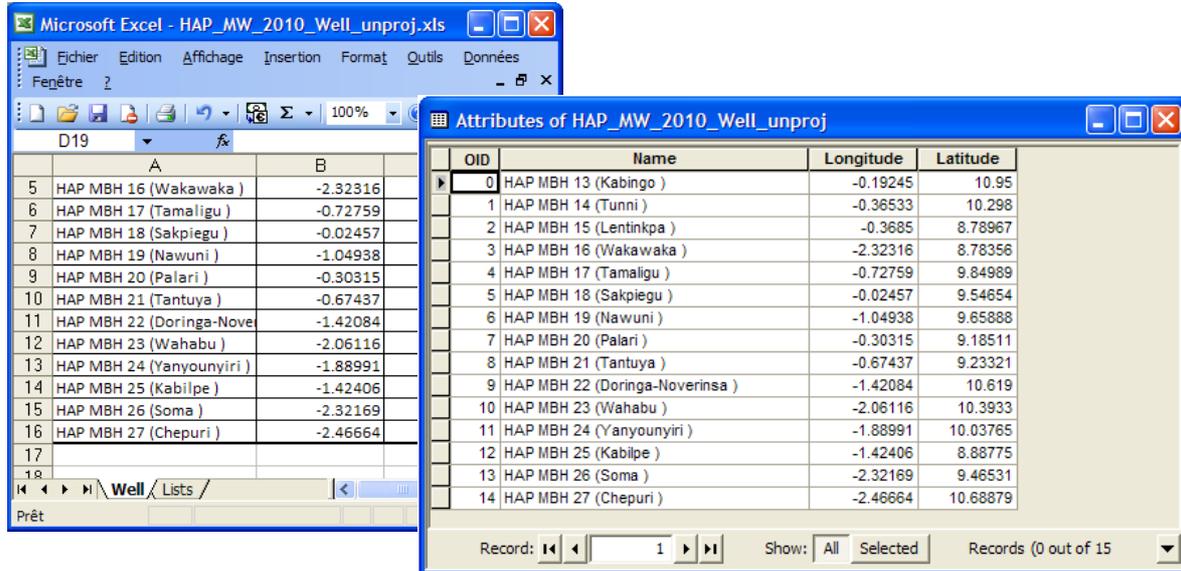
If data is not in digital format and represents objects to localise (e.g. well), coordinates must be input in a file (*ArcGIS, Excel, etc.*) and characteristics could be input in the same time or later. If data represent characteristics of objects (e.g. series), it has to be input in a separate file (*ArcGIS, Excel, etc.*) and will be linked once localised features will be created.

Each object must first be located as features (point, line or polygon) in a layer. Characteristics related could be integrated before the localisation of the feature (with the XY coordinates) or after when the layer is created.

1.1.2.1 Non digital external data preparation

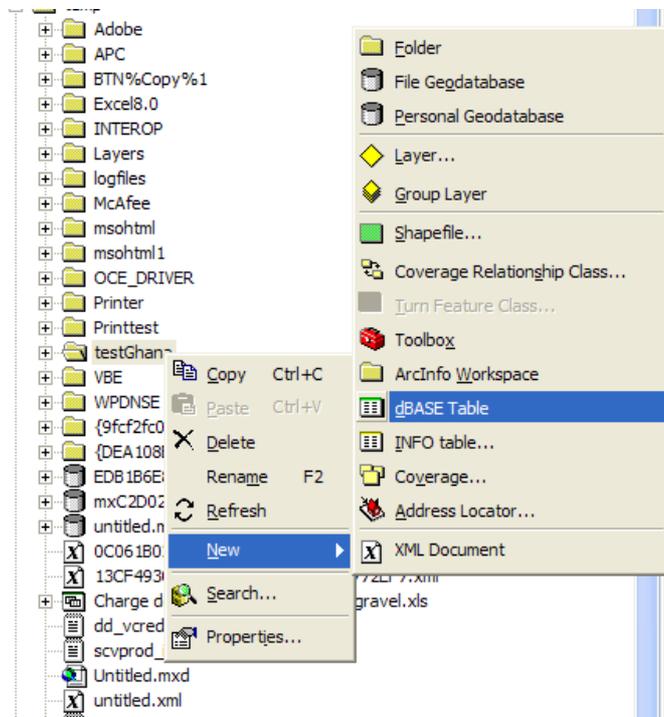
To localise objects, coordinates must be entered in two columns. File format can be an *Excel* sheet, a *dBase* table, a *Delimited text* file, an *Access* table, or any format recognize by *ArcGIS*. Information related to objects could also be input or could be link after the objects localisation. If coordinates are stored using more than one projection, they have to be

separated to be treated separately. The example below shows how to enter information in a *dBase* table in *ArcGIS*.

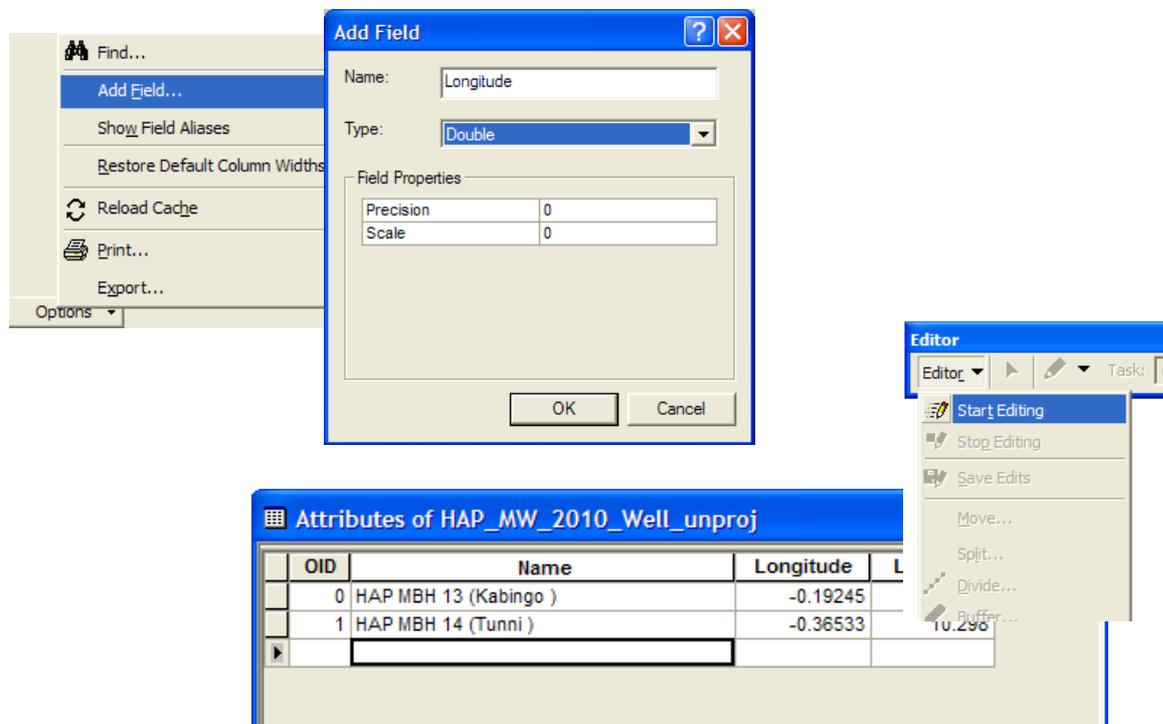


Input coordinates in ArcGIS

To create a new *dBase* table in *ArcGIS*, *ArcCatalog* must be use. The operation can be complete by a *right-click* on the destination directory (or database) using the menu *New-dBase Table*.



Fields can be added both in *ArcCatalog* and *ArcMap* using the menu *Options-Add field...* (*Preview* mode in *ArcCatalog* and only outside an edit session in *ArcMap*) but values can be input only in an edit session in *ArcMap*.



1.1.2.2 Digital external data preparation

If data is in digital format, input is not necessary but the source must be cleaned first. *ArcGIS* is not very powerful for formatting so it is a better option to use *Excel* or the native format of the external database (for example *Access*). Values could be corrected too if the correction is simple, but it will be more efficient in *ArcGIS* using the *Selection* and *Calculator* tools.

Before the integration to ArcGIS

Before the integration to *ArcGIS*, those modifications have to be applied to the source file:

- Field names must be change to fit exactly with the model field names.
- The format must be as a table format, composed of lines, columns and field names so all lines and columns not needed in the table must be removed
- Non needed fields could be removed. If not, ensure there is no point (.) in field names.
- Columns could be added if needed

If needed, data has to be separated to fit with the model tables. If the external format is *Excel*, each pertinent tables (depend of the data) must have a corresponding file. It is important to ensure that the column containing the ID is keeps in all files. This will be used temporally to identify features and make links before the generation of their *HydroID*.

Each file corresponding to a table in the model must after be saved in the *Delimited text* format. *ArcGIS* can read *Excel* and *dBase* formats but the *Delimited text* format generally gives better conversion results like numbers and special characters. If the external format is *Access*, *ArcGIS* can read files directly.

Integration to ArcGIS

Delimited text file or *Access* tables can now be loaded in *ArcGIS*. Once loaded, *Delimited text* file usually has to be converted (if the table has to be modified) in *dBase* format (or other ESRI format) because this is a format *ArcGIS* cannot edit. The conversion can be realized using the *Options-Export...* menu. If the format is *Access*, no conversion is needed.

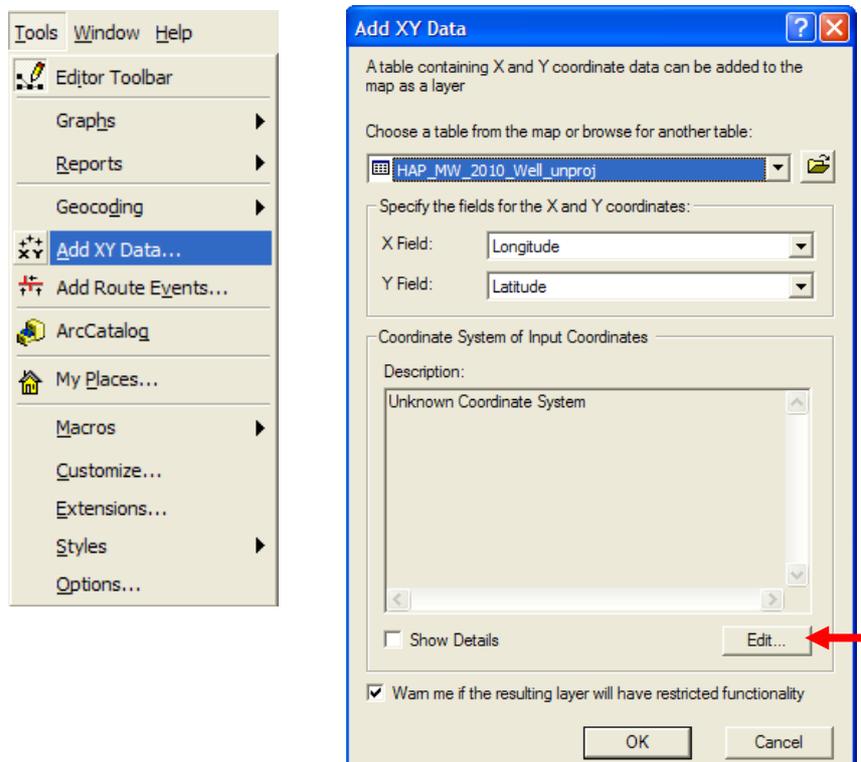
Once the table can be edited, values can be organised and standardized to fit with model domains using the *Selection* and the *Calculator* tools.

If coordinates are stored using more than one projection, they have to be separated to be treated separately. There will be one table by projection.

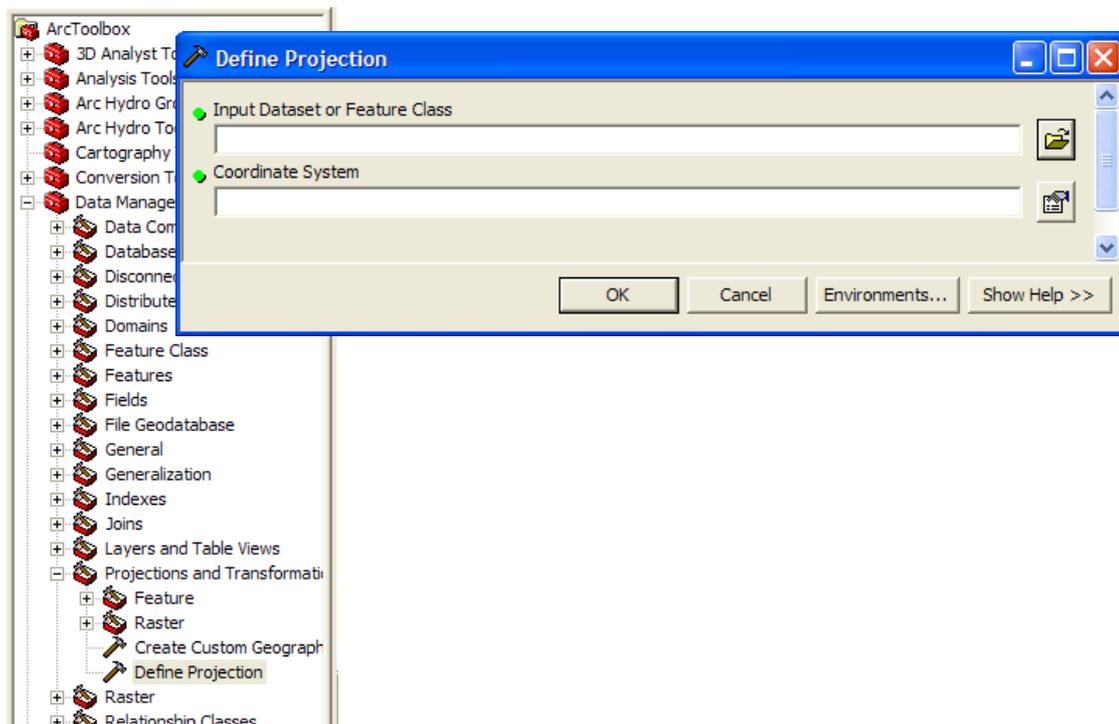
To confirm the projection of a coordinates set, a temporary layer (event) could be generate using the *Tools-Add XY data...* menu without using a projection. The projection is set in the dataframe properties so if a subset of generated points can be overlay with one of the database layer (e.g. Districts), it means the projection of the dataframe is the right one for this subset. Other points could then have a different projection or simply wrong coordinates. An additional field could be added to the table to identify the projection or a coordinate's problem. This field will be used to separate data that have to be treated separately for the spatial integration.

1.1.3 Localize points in an event layer

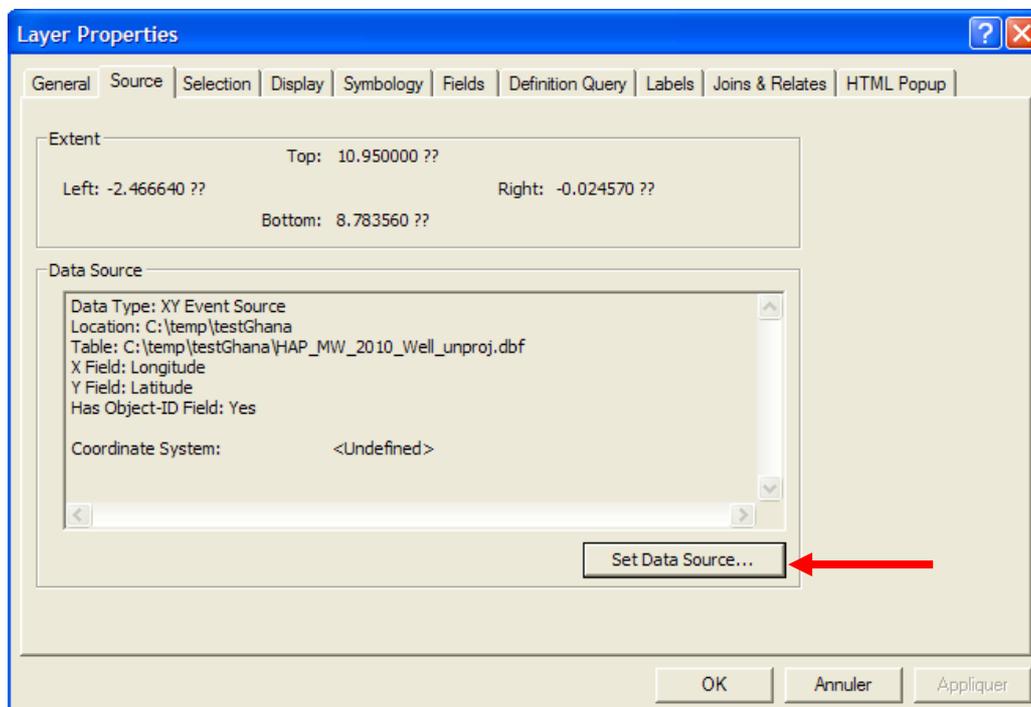
Once the file is complete with correct coordinates, points can be localized temporally in an event layer using *Tools-Add XY Data...* menu.



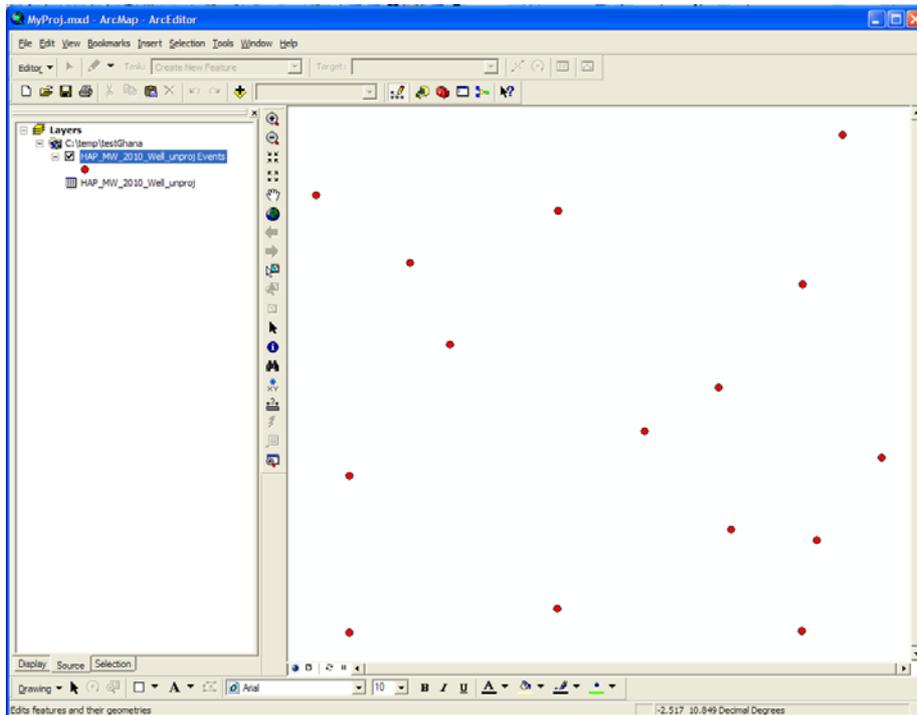
The coordinate system defined at the point 1. (or confirm at the point 2.2.1) can be assigned using the *Edit* button but can also be set after the treatment using the tool *Define projection* in *ArcToolBox*...



...or the button *Set Data Source* in the *Layer Properties* windows under the tag *Source* (see the point 1.1.3.1 for details about setting coordinate system).

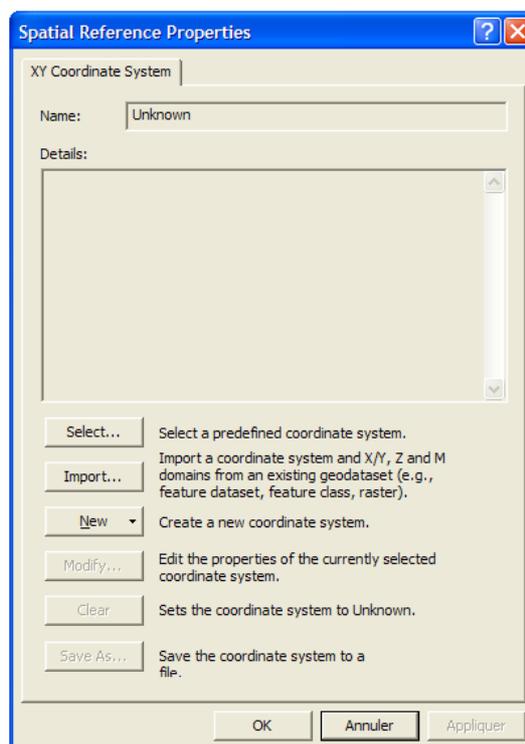


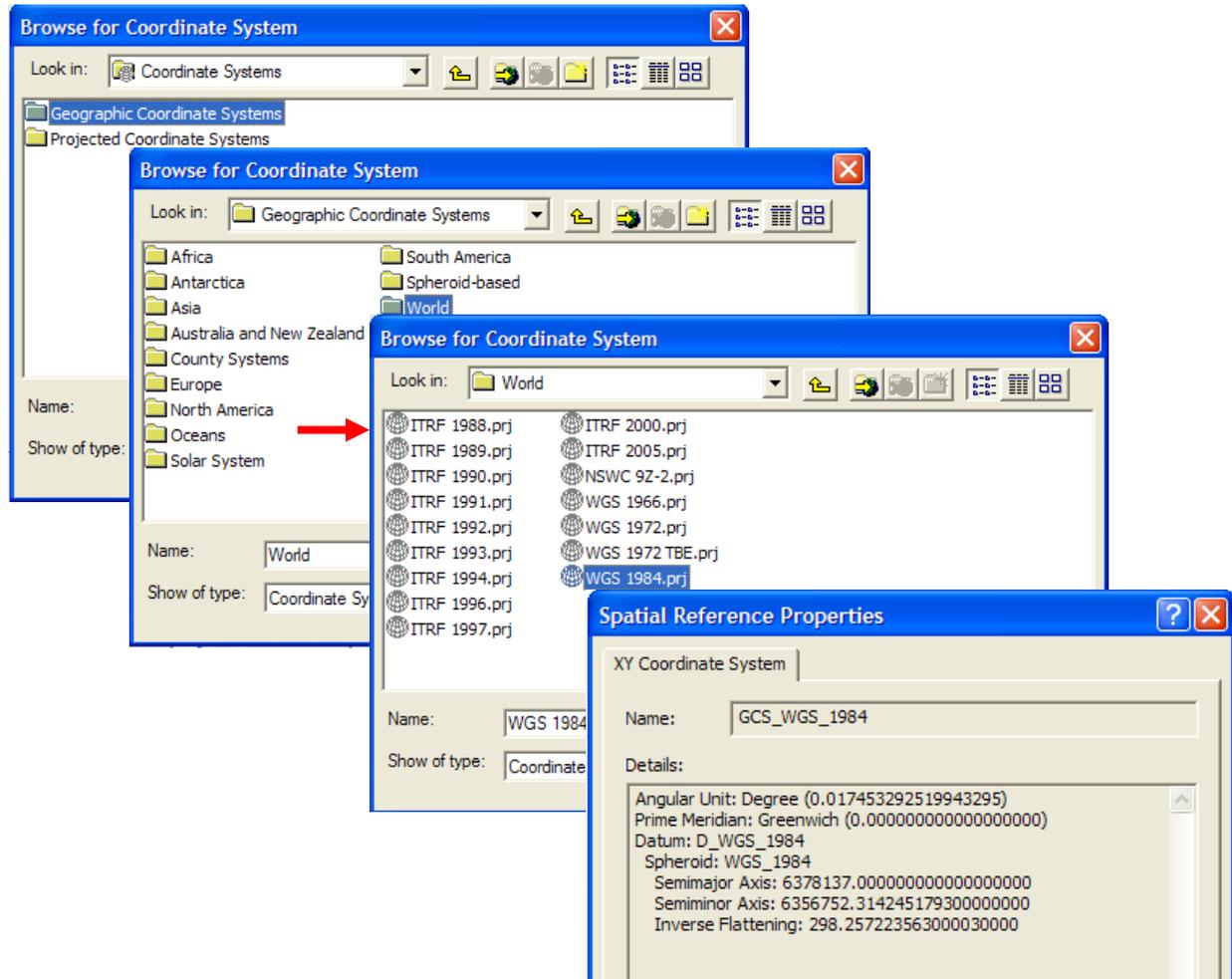
Once the treatment is completed, an event layer is added the active dataframe showing points.



1.1.3.1 Setting coordinate system

The coordinate system is usually set by selecting an existing .prj file or by importing similar spatial information from another layer. The button *Select* give an access the list of predefined files for projection.

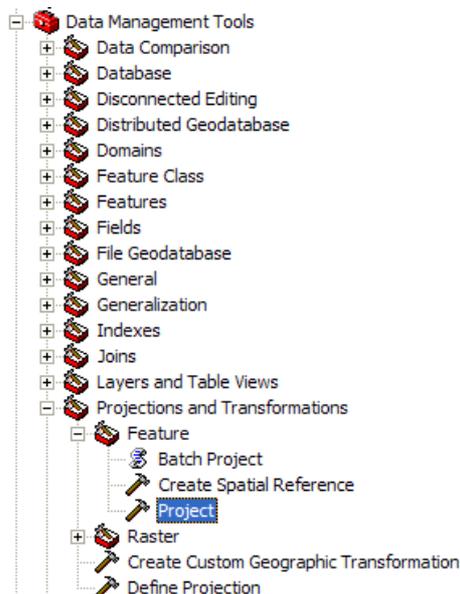




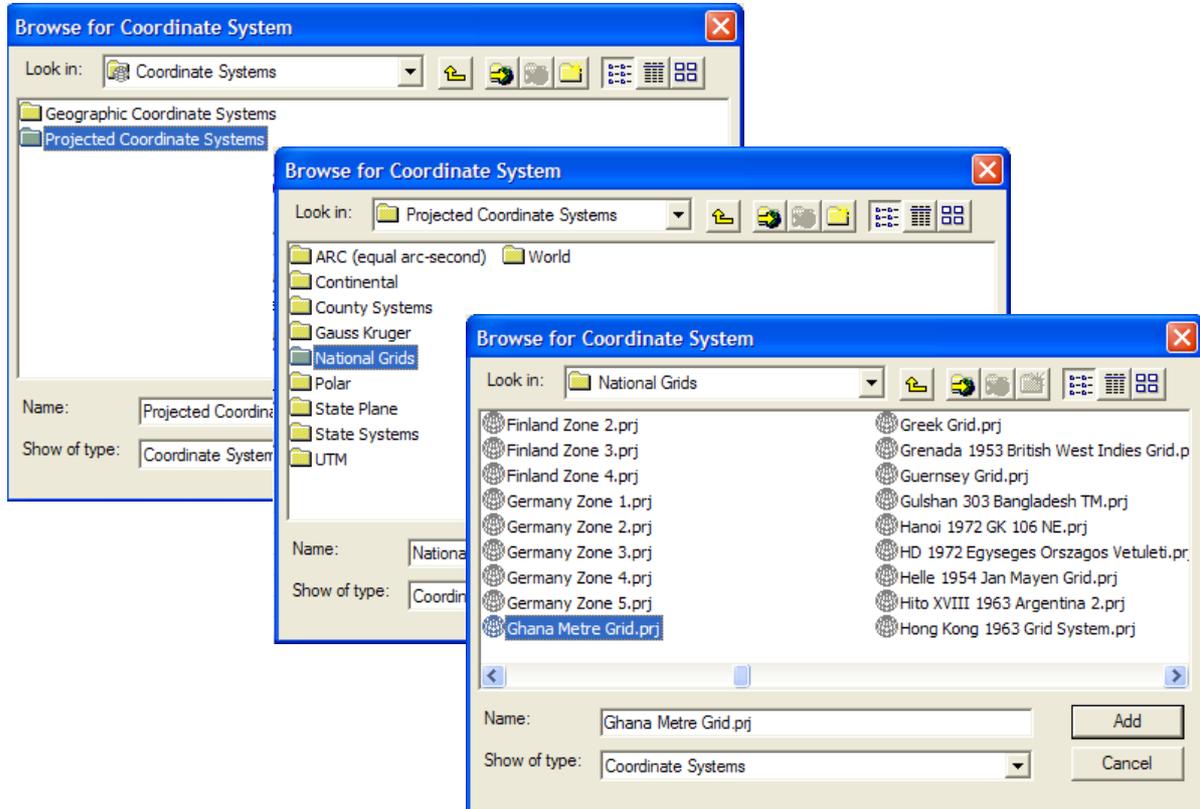
1.1.4 Projection of the event layer

The event layer is now ready to be project in the projection of the main database. It is important to note that this step has to be realized only if the projection of the event layer is not the same than the database one.

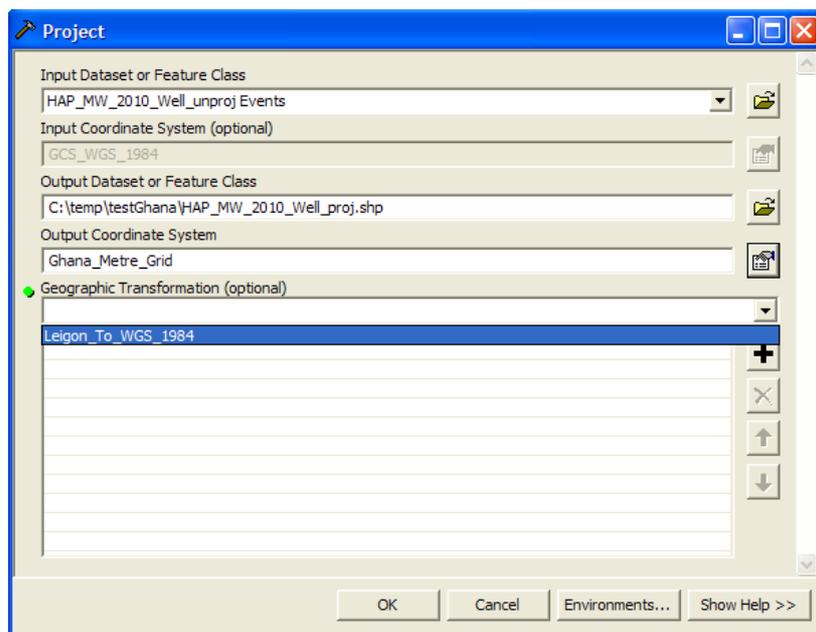
The *Project* tool in *ArcToolBox* has to be used to realize this operation.



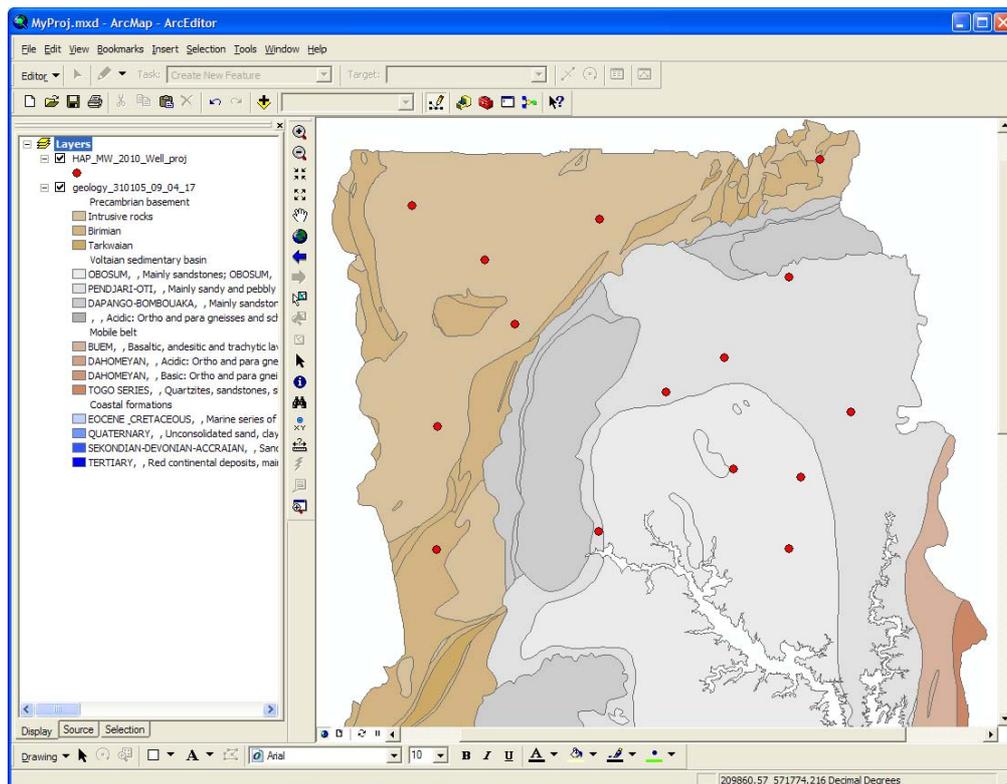
The event layer can be drag-and-drop in the *Input Dataset or Feature Class* field. The input projection will be assigned automatically. The name of the output data can be modified in the *Output Dataset or Feature Class* field if needed. The output coordinate system can be selected in the list of predefined files for projection using the button *Select* or can be imported from another layer with similar spatial information.



It is very important to select the option *Leigon_To_WGS_1984* in the *Geographic Transformation* field to ensure a transformation between the two datum.



After the operation, data are now in the same coordinate system as the main database and can be overlay with other layers.



1.1.5 Assigning XY coordinate

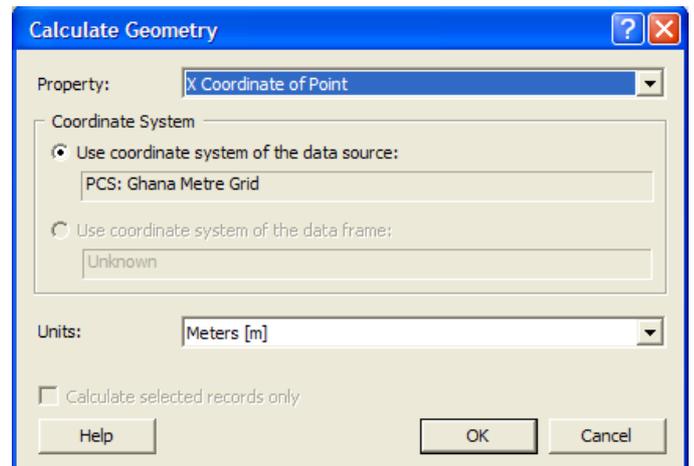
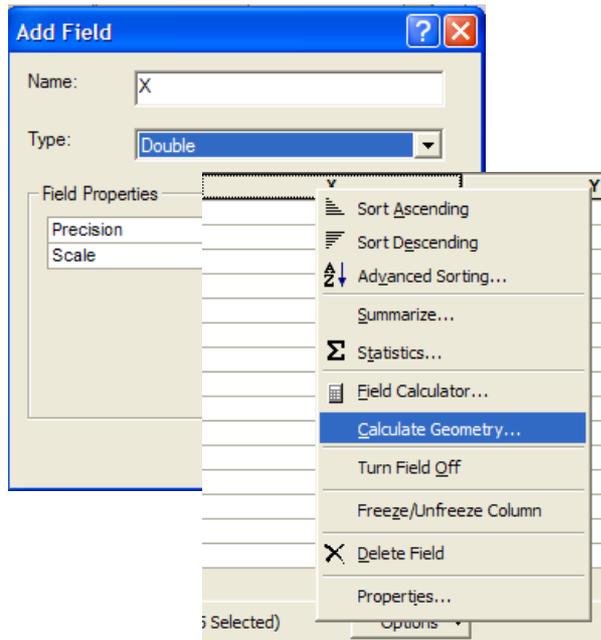
There are two methods to integrate the information to the database. The *copy-paste* method or the *ArchHydro* tools method.

If the copy-paste method is used, features are already created and the system will simply copy them in the database. In this case, an update of XY based on the new projection is necessary only if the source projection is not the same than the database one and to ensure correct coordinates information.

If the *ArchHydro* tools method is used, XY coordinates must be recalculated only if the source projection is not the same than the database one. It is important to note that usually, an event layer is generated with the objective to recalculate XY coordinates with the correct projection. Otherwise, the table can be use directly with *ArchHydro* tools, without modification.

To recalculated new XY coordinates, two fields have to be added (if they do not already exist). Values will be automatically calculated using a *right-click* on the field title and *Calculate Geometry...* menu.

This treatment can be used anytime information on XY coordinates are necessaries...



Attributes of HAP_MW_2010_Well_proj

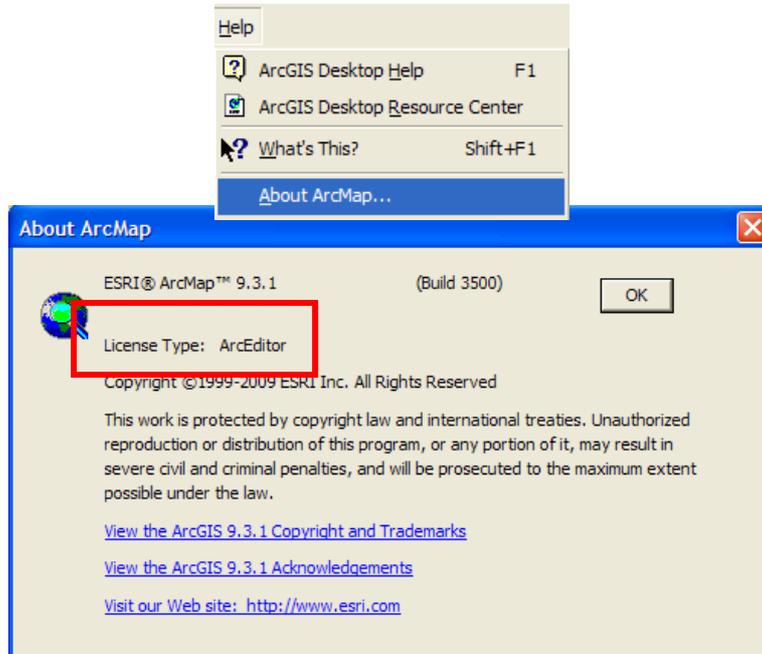
FID	Shape *	Name	Longitude	Latitude	X	Y
0	Point	HAP MBH 13 (Kabingo)	-0.19245	10.95	362544.021094	694540.933536
1	Point	HAP MBH 14 (Tunni)	-0.36533	10.298	343797.638626	622390.15601
2	Point	HAP MBH 15 (Lentinkpa)	-0.3685	8.78967	343755.206591	455591.99918
3	Point	HAP MBH 16 (Wakawaka)	-2.32316	8.78356	128738.62867	455114.523224
4	Point	HAP MBH 17 (Tamaligu)	-0.72759	9.84989	304166.05827	572780.933244
5	Point	HAP MBH 18 (Sakpiegu)	-0.02457	9.54654	381361.981969	539375.849965
6	Point	HAP MBH 19 (Nawuni)	-1.04938	9.65888	268874.571446	551647.461713
7	Point	HAP MBH 20 (Palari)	-0.30315	9.18511	350860.69937	499333.321636
8	Point	HAP MBH 21 (Tantuya)	-0.67437	9.23321	310066.599038	504594.009084
9	Point	HAP MBH 22 (Doringa-Noverinsa)	-1.42084	10.619	228253.002163	657849.932965
10	Point	HAP MBH 23 (Wahabu)	-2.06116	10.3933	158112.61645	633053.986627
11	Point	HAP MBH 24 (Yanyounyiri)	-1.88991	10.03765	176754.998401	593663.359114
12	Point	HAP MBH 25 (Kabilpe)	-1.42406	8.88775	227660.75253	466405.211316
13	Point	HAP MBH 26 (Soma)	-2.32169	9.46531	129176.171342	530517.72957
14	Point	HAP MBH 27 (Chepuri)	-2.46664	10.68879	113864.193827	665917.342711

Record: 0 Show: All Selected Records (0 out of 15 Selected) Options

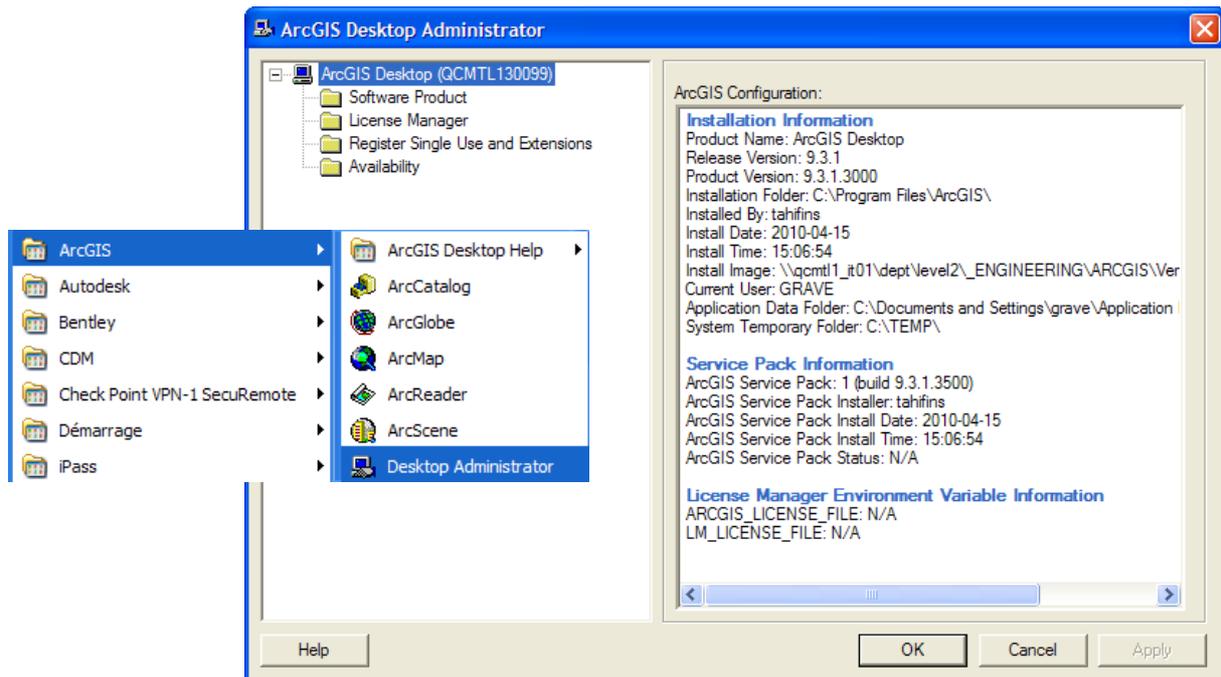
1.2 Input data to the WRC groundwater database

1.2.1 Checking and setting ArcGIS license level

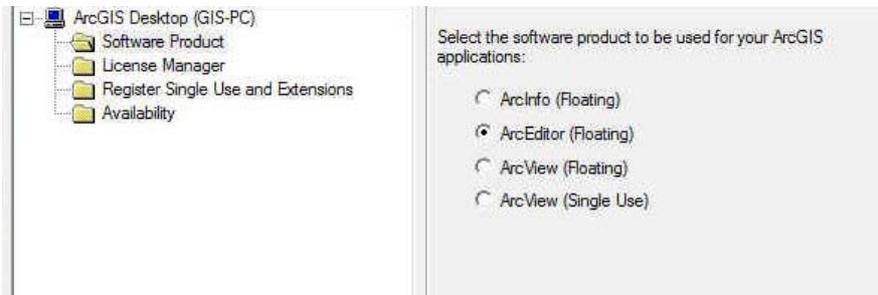
To edit the WRC groundwater database in *ArcGIS*, an *ArcEditor* license level is required. The active level can be checked using the *Help-About ArcMap...* or *Help-About ArcCatalog...* menus.



To change the license level, all *ArcMap* and *ArcCatalog* sessions must be closed. The *ArcGIS Desktop Administrator* can be started using the *All Programs-ArcGIS* menu under *Windows Start* menu.



Under the *Software Product*, *ArcEditor* has to be selected. When an *ArcMap* session will be started, the system will looking for the license file associated with the license. If the license is not available or no more valid, the session will not start.

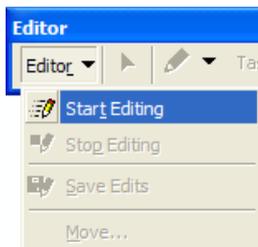


1.2.2 Input data

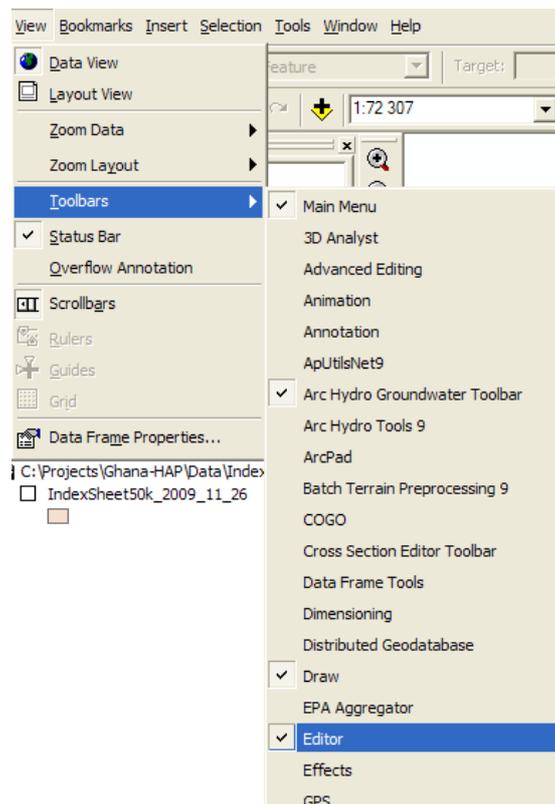
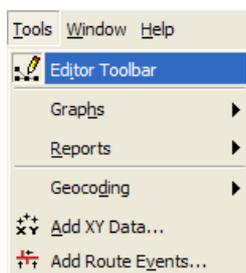
First, there are three principal steps to do when adding borehole information:

- a) Create features (see 1.1 *Data preparation for the WRC groundwater database integration*), and integrate them to the database
- b) Adding IDs for each element added and make links using them in each related tables
- c) Input feature attributes

In *ArcMap*, data input in the WRC groundwater database can be accomplish using a manual method or *ArcHydro* tools with templates (*Excel* or *Access* format). In any cases, an edit session must be start using the *Start Editing* menu in the *Editor Toolbar*. In *ArcGIS*, the edit session is related to the entire database or directory. So, many tables and layers can be edited at the same time.

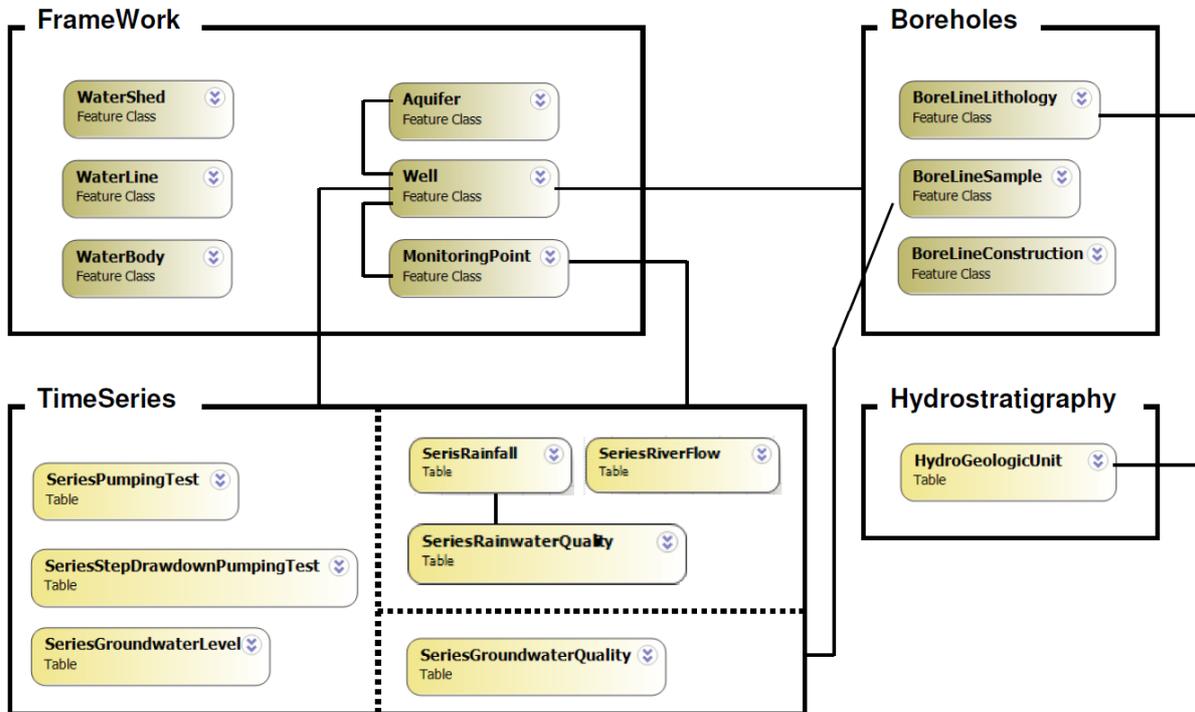


To access the *Editor Toolbar*, use the *Tools-Editor Toolbar* menu or select *Editor* in the toolbar list accessing by the *View-Toolbars* menu.



It is important to follow the database workflow when creating/importing new data to ensure data integrity (e.g. do not enter groundwater quality data before entering the well from which the groundwater quality sample was taken). The well feature layer is the center of the database and data related to the well itself must be input first.

ArchHydro GroundWater data model for WRC



1.2.2.1 Understanding the Hydro-ID

The *Hydro-ID* is a unique number used to identify an entity. Each new record in a table from the WRC groundwater database must have a unique ID. The *Hydro-ID* is assigned automatically by the system for all features class tables and will be used to make a link with related information present in other tables. The example bellow shows the utilisation of IDs in relationship.

Wells	
Hydro-ID	Aquifer-ID
1	A
2	C
3	E
4	D
5	E
6	D
7	C
8	C
9	A
10	D

Monitoring points	
Hydro-ID	Well-ID
I	3
II	5
III	6
IV	8
V	9
VI	10

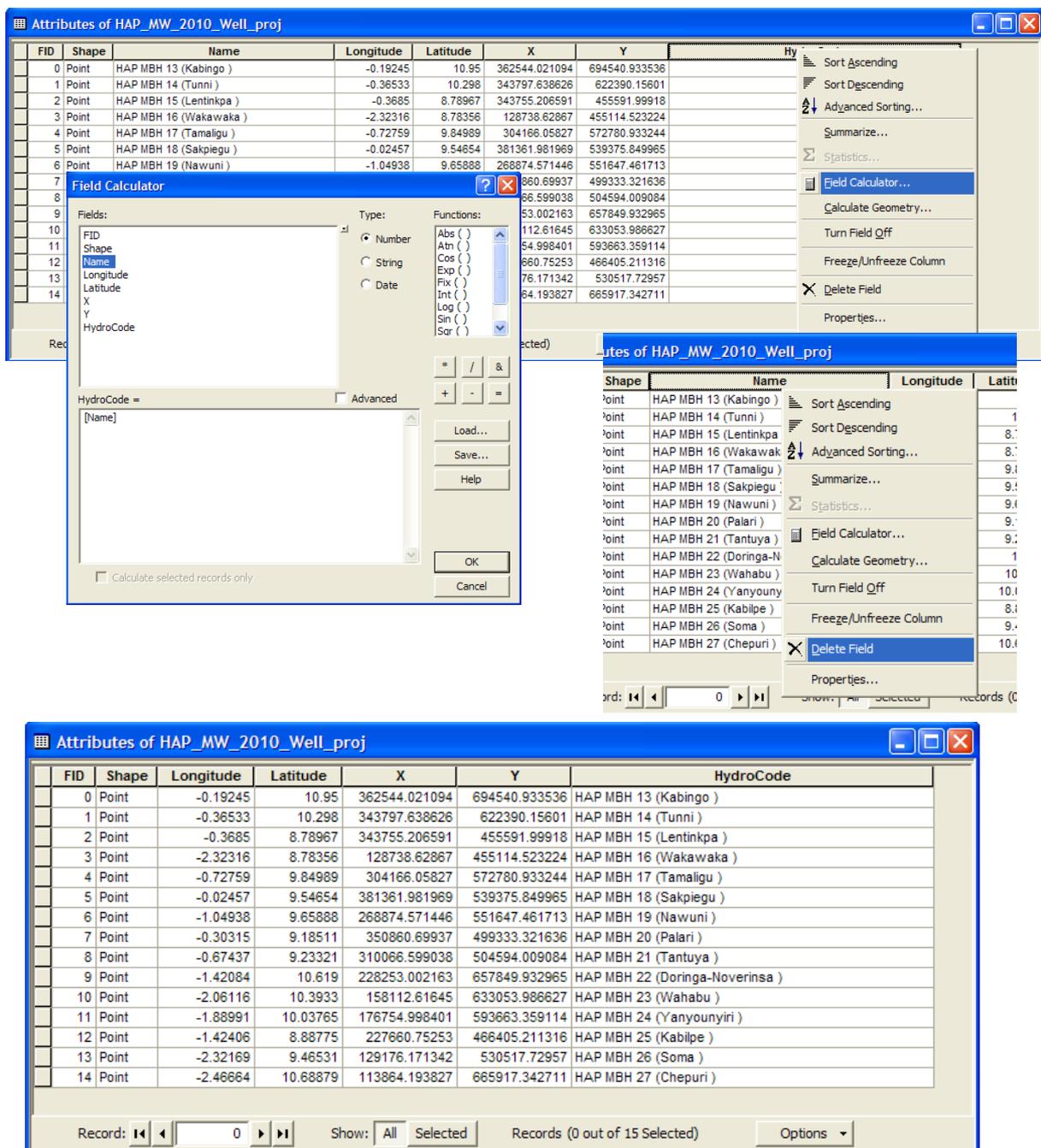
Aquifer	
Hydro-ID	Name
A	Name1
B	Name2
C	Name3
D	Name4
E	Name5

1.2.2.2 Input data using manual method

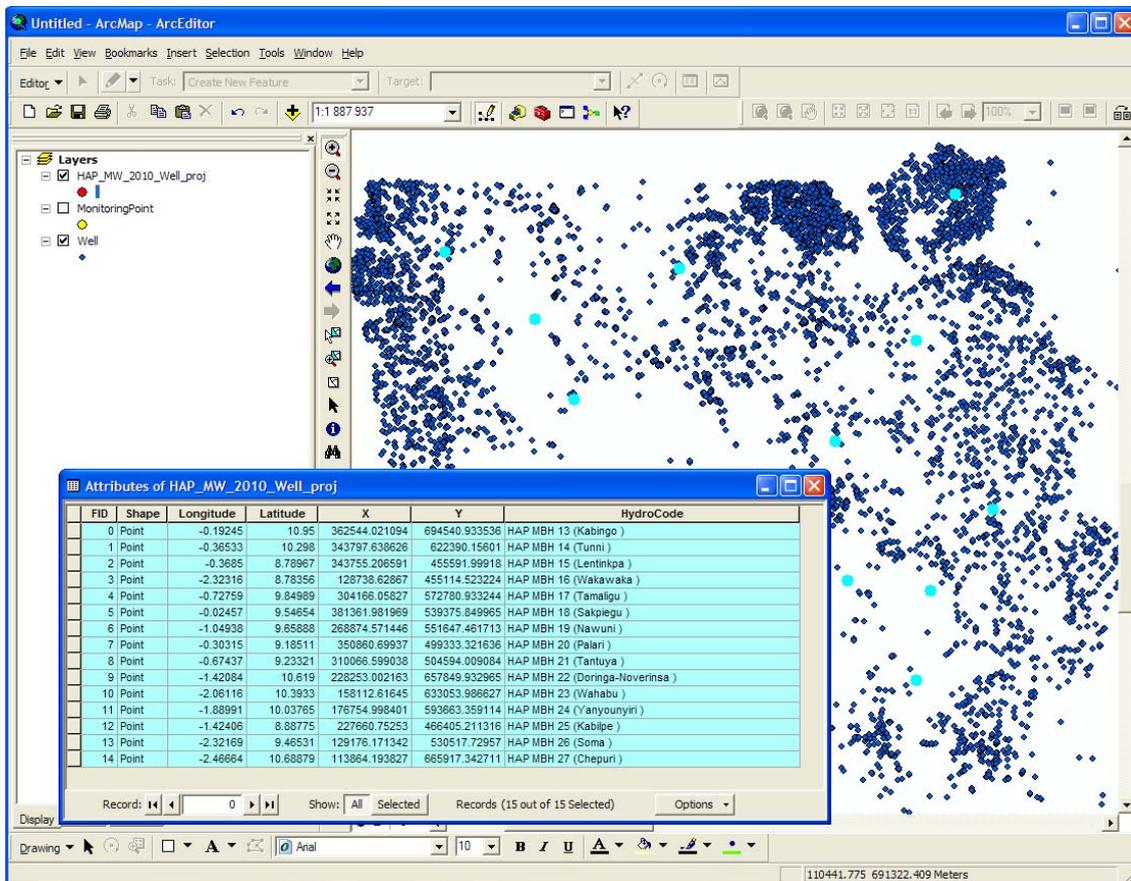
Feature input

To integrate in an efficient way points from a layer to the Database, fields with values to transfer (*Longitude, Latitude, HydroCode*) must have exactly the same name as fields in the destination layer.

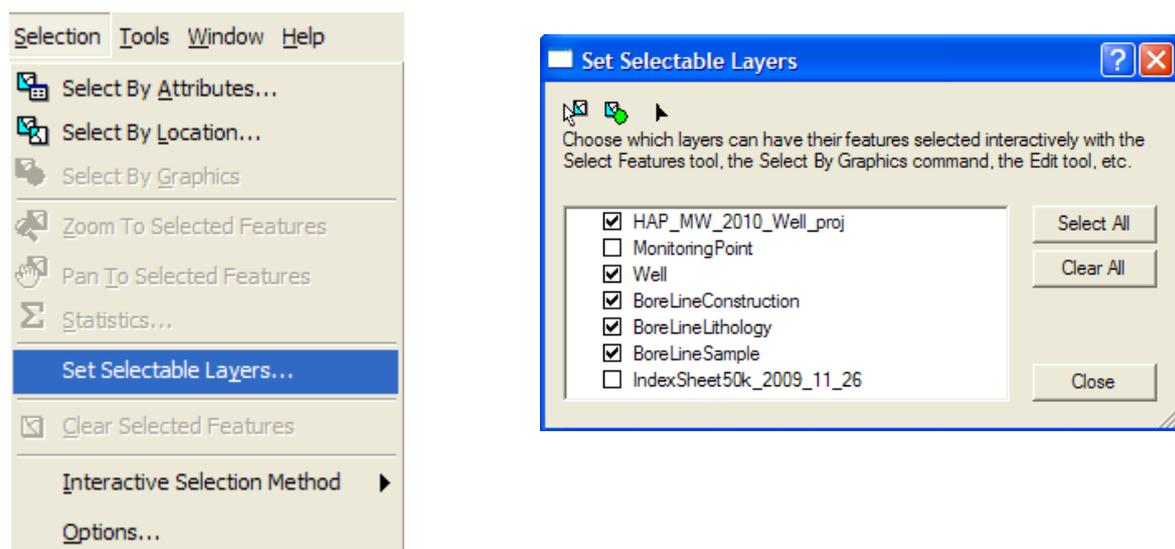
ArcGIS does not allow modification to a field name. A new field must be created and using the Calculator tool (accessing by a *right-click* on the field name and the *Field Calculator...* menu), values can be transferred from the old field to the new one. The old field can be deleted at the end of the treatment (assessing by a *right-click* on the field name and the *Delete Field* menu).



Once points are ready to be integrated, they must be selected in the view or in the table. If the selection is made in the view, ensure that only points to integrate are selected. If another layer of the same type of features (e.g. well and monitoring point are both points layers) is selectable and contains selected features, those features will be transferred too.

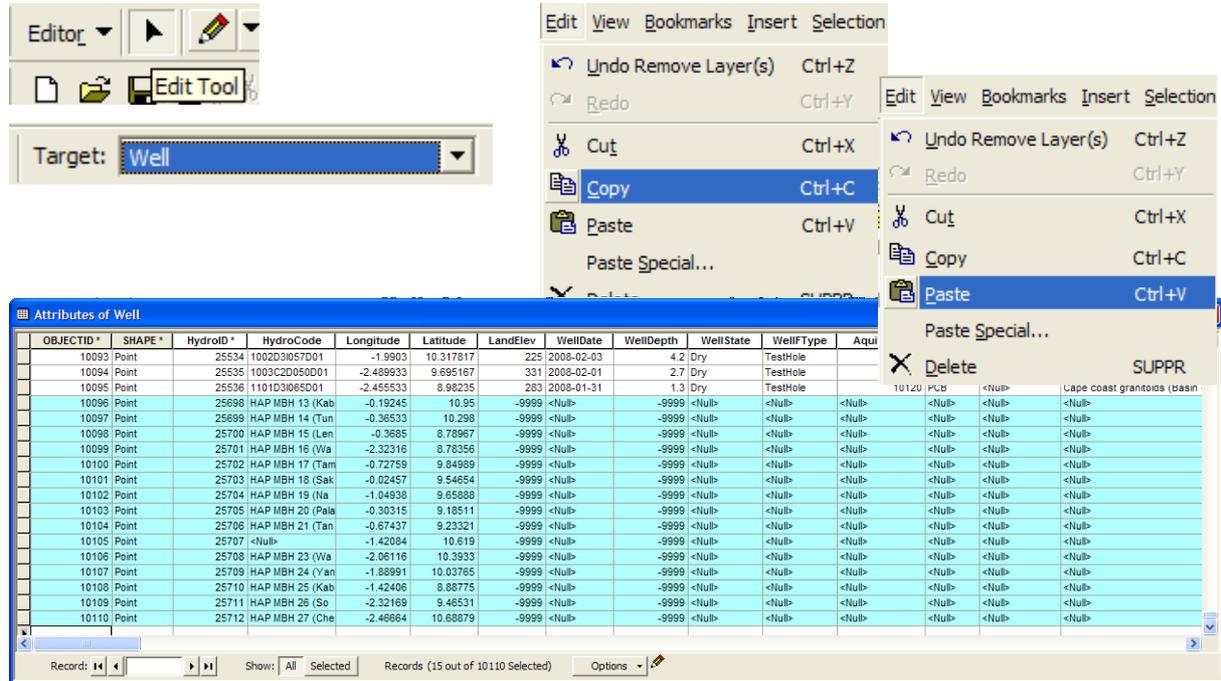


The management of selectable layer can be operate using the *Selection-Set Selectable Layers...* menu.



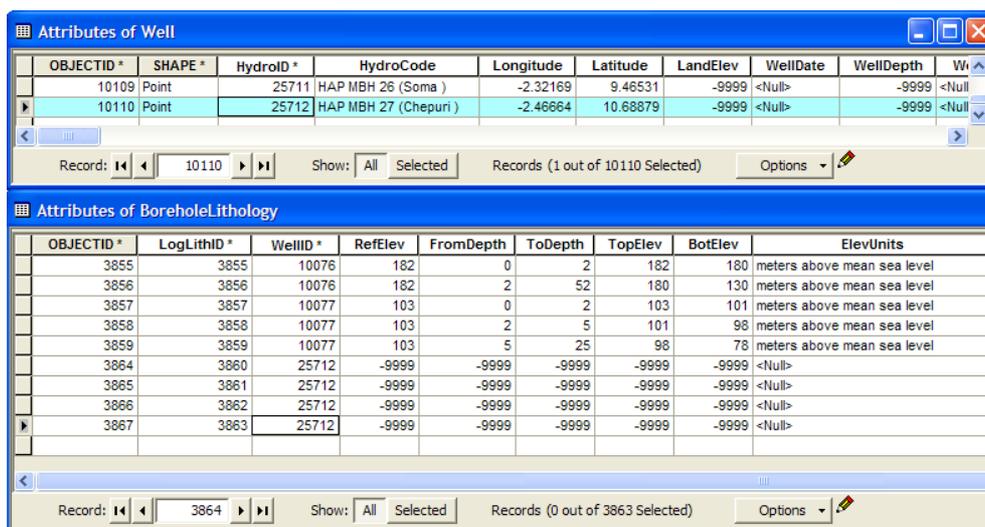
Once points to transfer are selected, the *Edit* tool in the *Editor* toolbar has to be selected and *Copy* menu can be used using a *right-click* in the view. After ensuring that the target in the *Editor* toolbar is the destination layer, the *Paste* menu, also obtained by a *right-click* in the

view can be used to integrated points. Points are automatically copied in the destination layer and records are added in the features table. Note that values present in fields with the same names have been transferred. Information related to new points can after be input manually in the table.

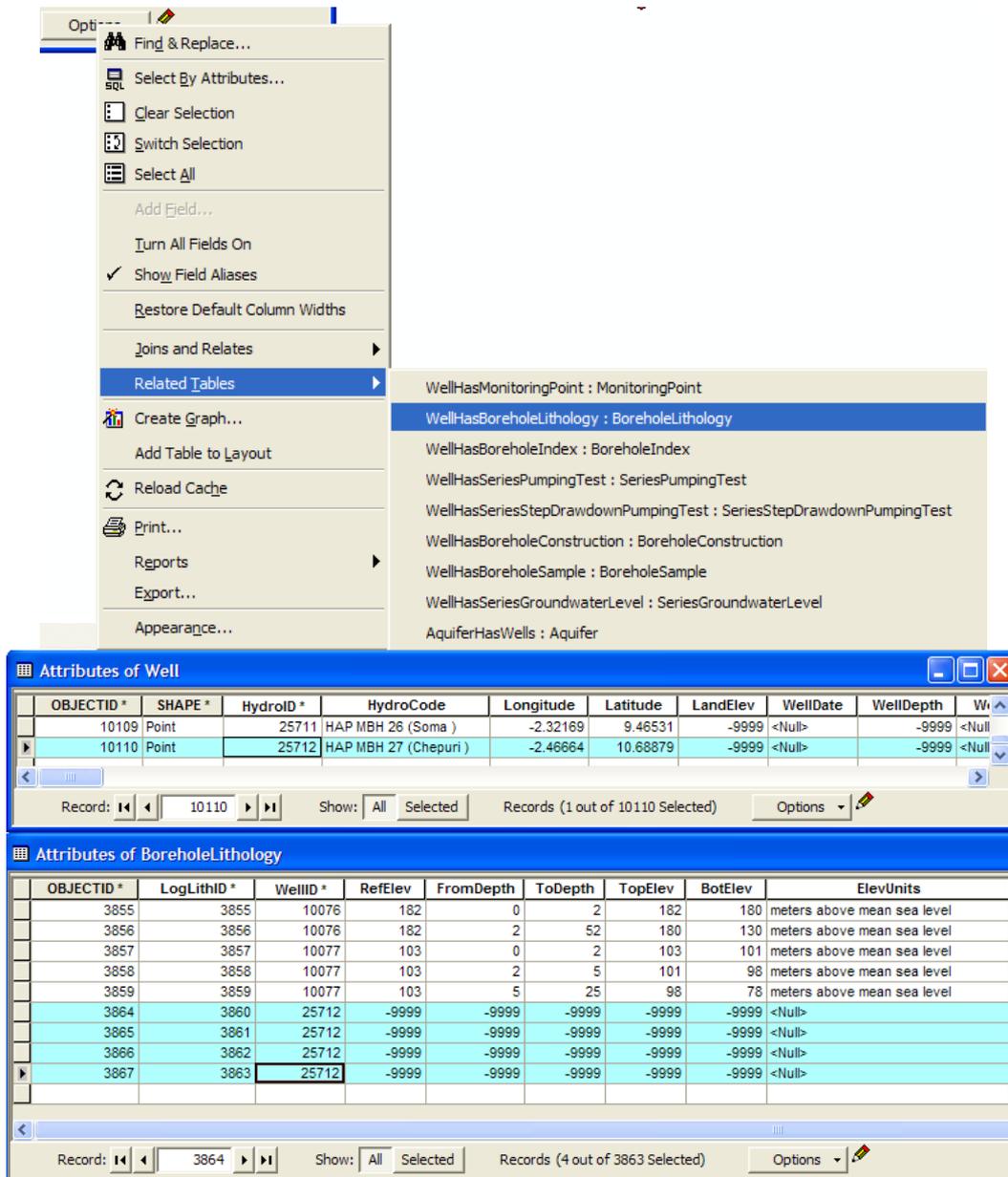


Related table input

To input information in related tables, for example lithography, many new records must be added to the corresponding table. Before adding any information, the ID must be entered first so the system populated every field with default values. The foreign ID can after be input to create a link between both tables. This can be done by a *copy-paste* using the *right-click* menu.



Once the link is created using the foreign ID, the relation must be check by selecting the corresponding relationship using the menu *Options-Related Tables*. This operation ensures the database integrity. Once the relationship is verified, information related can now be input manually in the table.



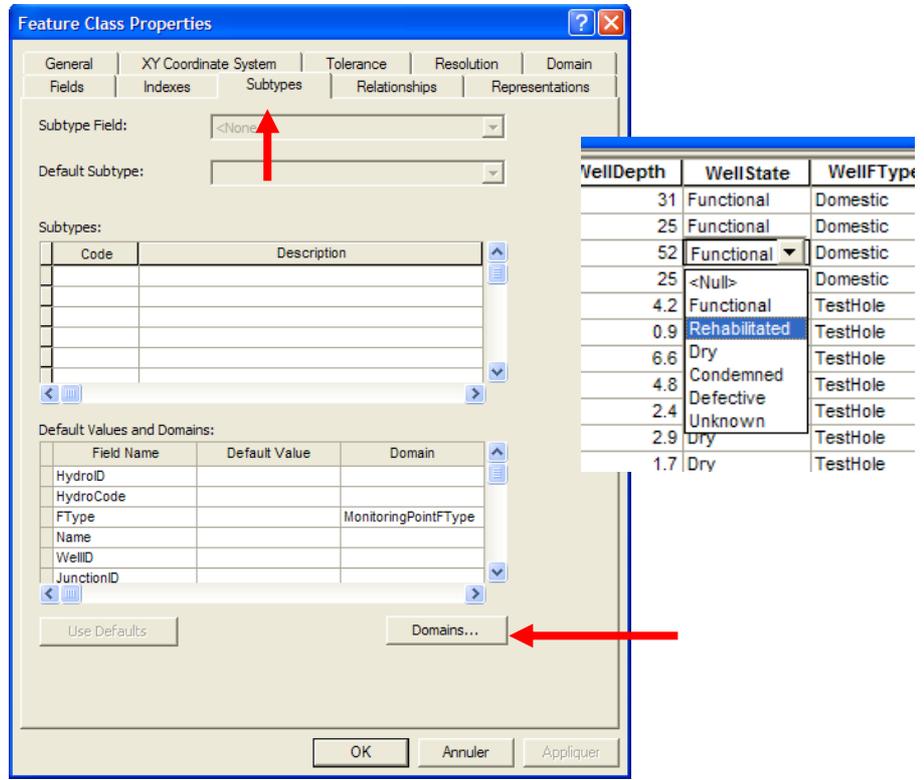
1.2.2.3 Input data using ArcHydro tools

ArcHydro GroundWater toolbar allows to automatically input data (See 4.1.1 Text Import menu). Information must be formatted first in *Delimited text* format. For each model tables, templates have been developed in *Excel* format to help data preparation (... \BoreholeDatabase\Templates)

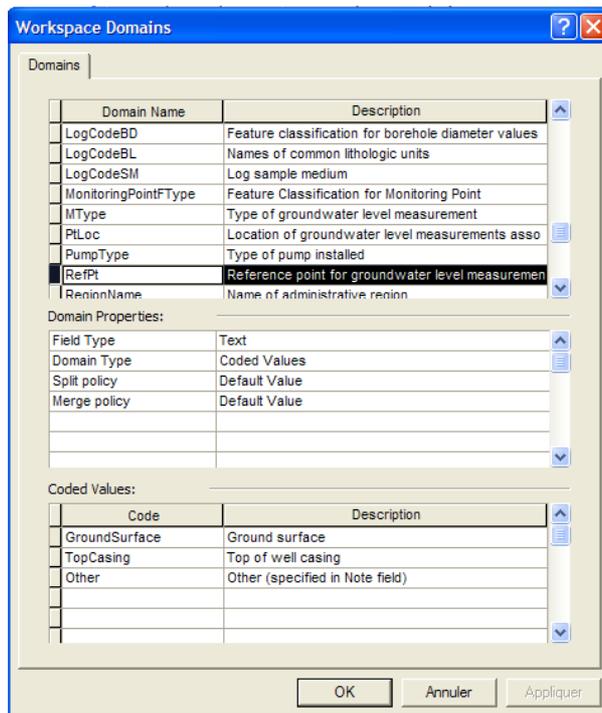
1.2.3 Updating domains

Some fields of the WRC groundwater database are using domains that define what values are allowed. They are used to constrain the input. The two types of attribute domains are range domains (range between minimum and maximum values) and coded value domains (list of defined values). Each domain has a name, description, and specific attribute type to which it can apply.

Manipulations to update a domain must be realized in *ArcCatalog*. In any features class or table properties window, the list of domains assigned to the database is available under the *Subtypes* tag by clicking on the *Domains...* button.



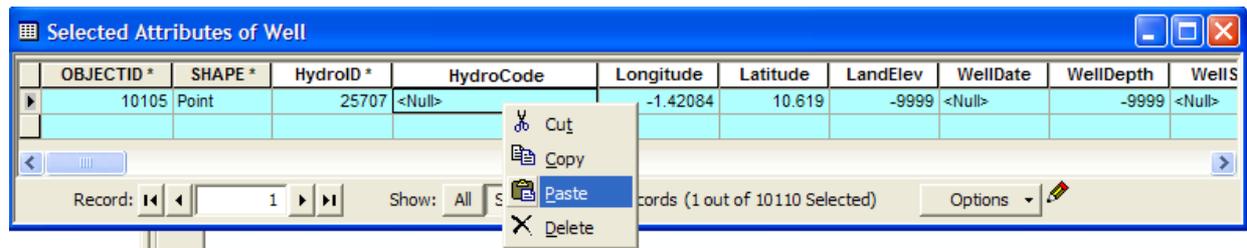
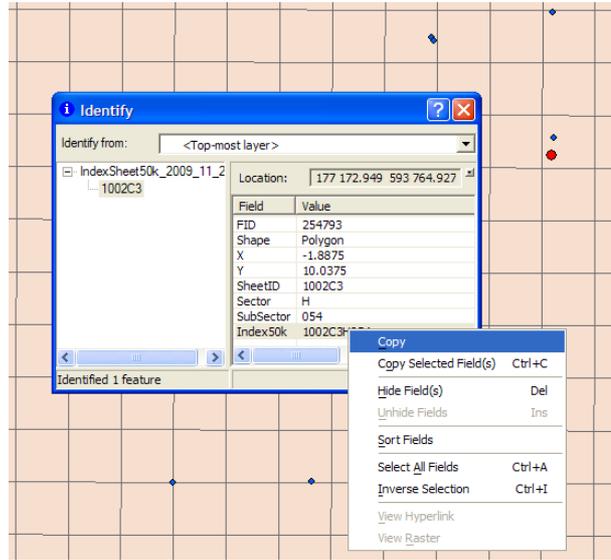
For each domain, there is a description, domain properties and a range or a list of values. Range can be modified or value can be added or removed from the list.



1.2.4 Setting the HydroCode

Each well must have a *HydroCode*. It is assigned using the layer *IndexSheet50k_2009_12_17.shp* overlay with the *Well* layer. The first part of the *HydroCode* is composed of the value present in the *Index50k* field of the index polygon where the feature is located. This value can be *copy-paste* from the index table to the destination table using the *right-click* menu in the table.

The second part is a letter represents the kind of feature: “B” for a successful borehole, “D” for a dry borehole and “W” for a hang-dug well. The third part is a sequential number for well of the same category. For example, if there is already two dry boreholes in the same index, the *HydroCode* of the third one will finish with a “03”.



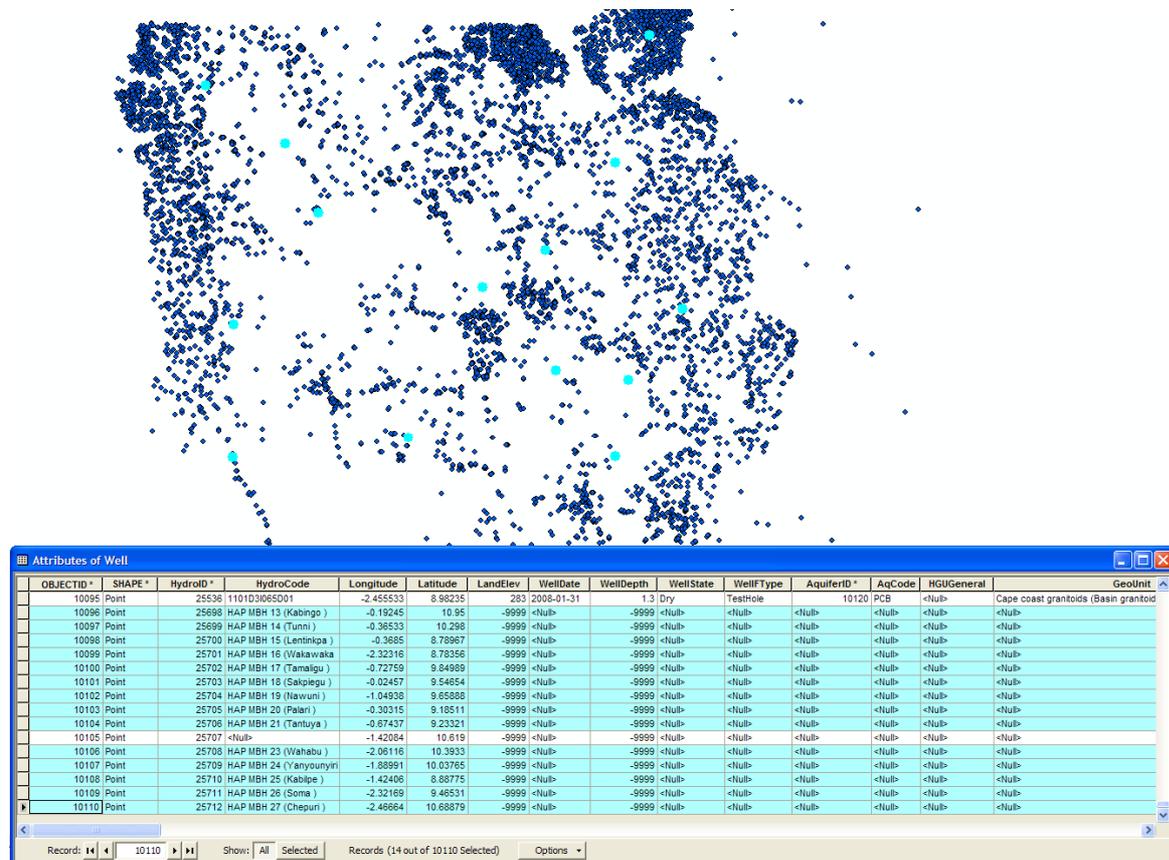
2. DATA ANALYSIS

A lot of time, work and energy are invested to maintain a database quality. Once the database is operational, the next step is to obtain results and answers. Those can after be extracted or mapped to be published.

ArcGIS presents many efficient tools to extract and manage information from a database. They all interact together.

2.1 Working with selection

Selection tools are used first to query the database. Features or records selected are highlight in the view (for layers) and in the table. A set of selected element is called a selection.



Using a selection is also a way to restraint the application of a process, a way to indicate to the system a subgroup of features or records to work with. If there are selected elements, the treatment will be applied only for those ones. If there is no selected element, the treatment will be applied for all elements.

2.1.1 Selection methods

Selection can be realized using four methods:

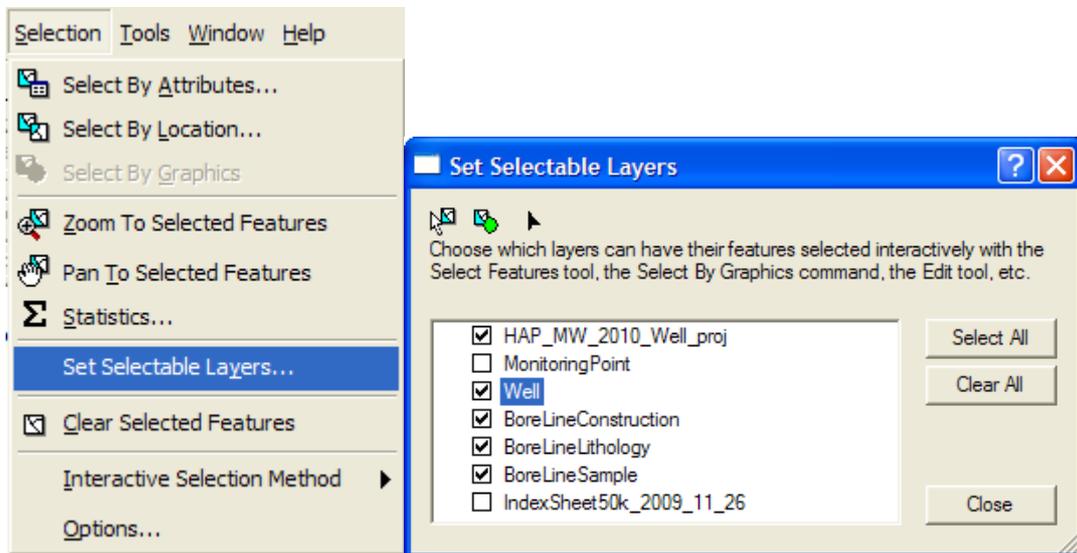
- *Create a new selection:* this method is the default method and represent 99% of cases. Any existing selection is cleared and the new selection is applied.
- *Add to Current Selection:* this method keeps any existing selection and realized a merge with the new selection.

- *Remove From Current Selection:* this method is used with an existing selection. Elements corresponding to the request become unselected but other already selected stay selected.
- *Select From Current Selection:* this method is used with an existing selection. The new selection will be applied inside the existing selection only. Unselected records will stay unselected. The result will be a subset of the existing selection.

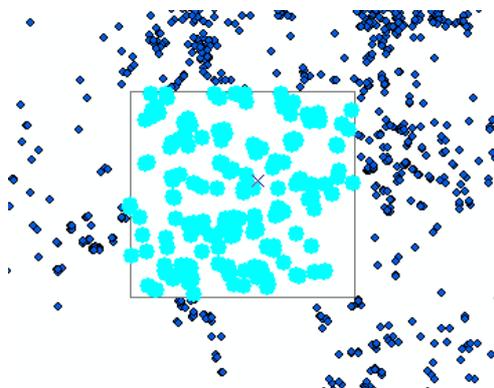
2.1.2 Manual selection

In a view, the selection can be realized manually using the *Select Features* tool  or the *Edit* tool  inside an edit session.

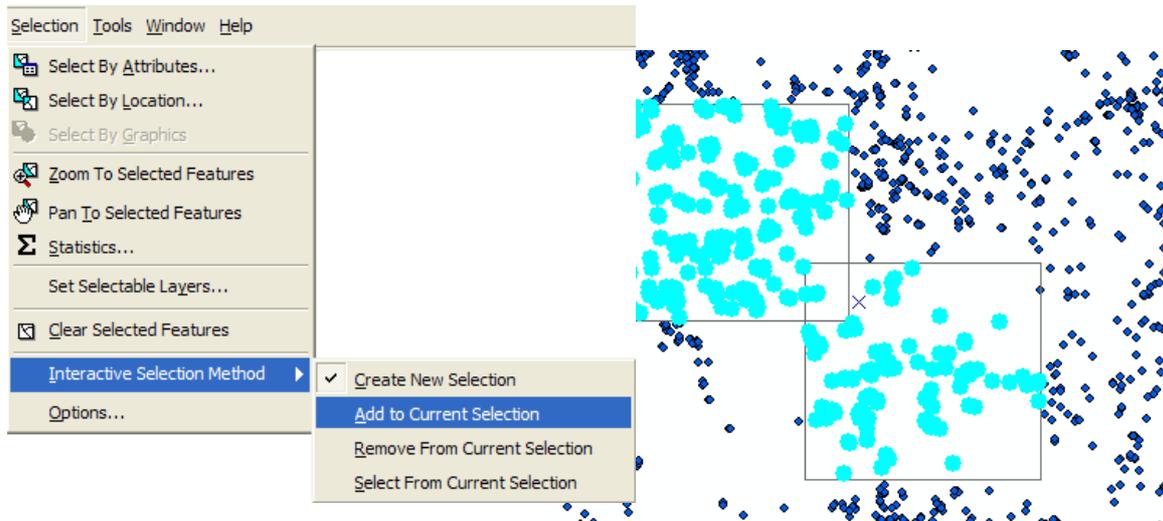
To ensure features of the layer will be selected, the layer must be first checked using the *Selection-Set Selectable Layers...* menu.



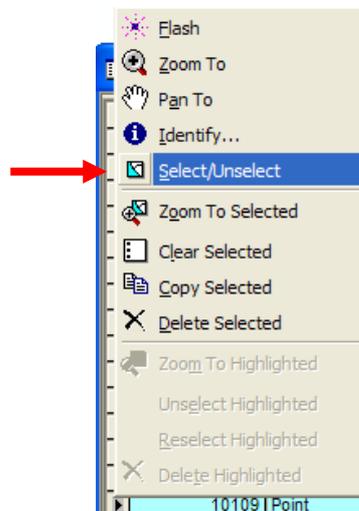
The manual selection can be realized using a *click* or a rectangle on the view. Using the *Shift* key allows adding or removing features to the selection set. Corresponding records will be selected automatically.



The method can also be set using the *Selection-Interactive Selection Method*.



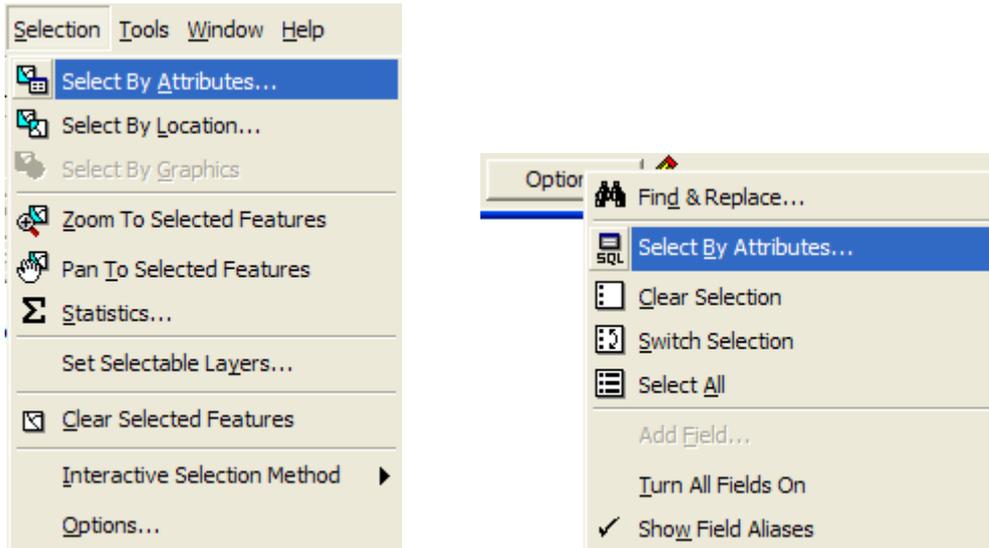
In a table, records can be selected using a *click*. Using the *Control* key allows adding or removing features to the selection set. This can also be realized by a *right-click* on the arrow on the left side of the record and using the *Select/Unselect* menu. Using the *Shift* key allows selecting one record to another. If the table is a features table, corresponding features will be selected automatically.



2.1.3 Selection by attributes

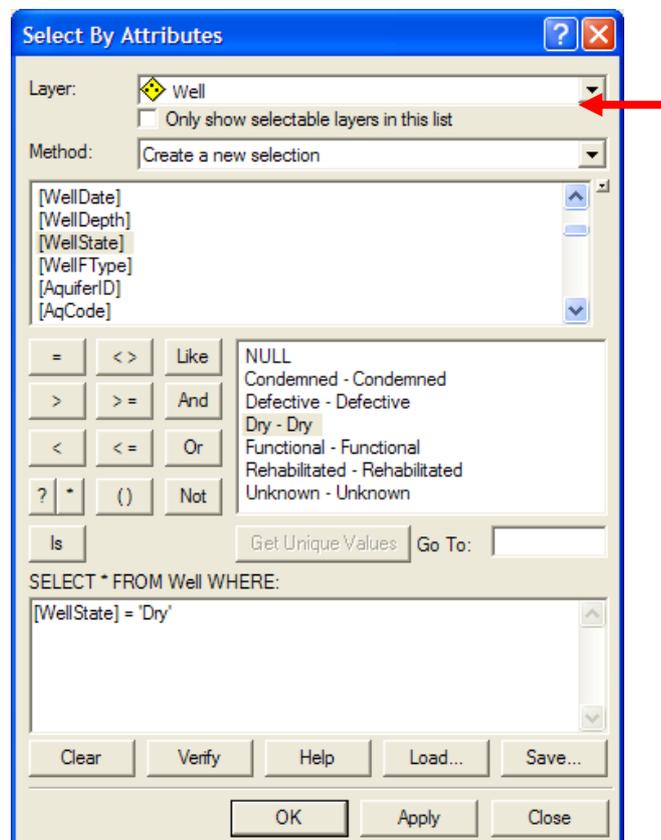
The selection by attributes is based on field values in a table. The selection is realized using a query.

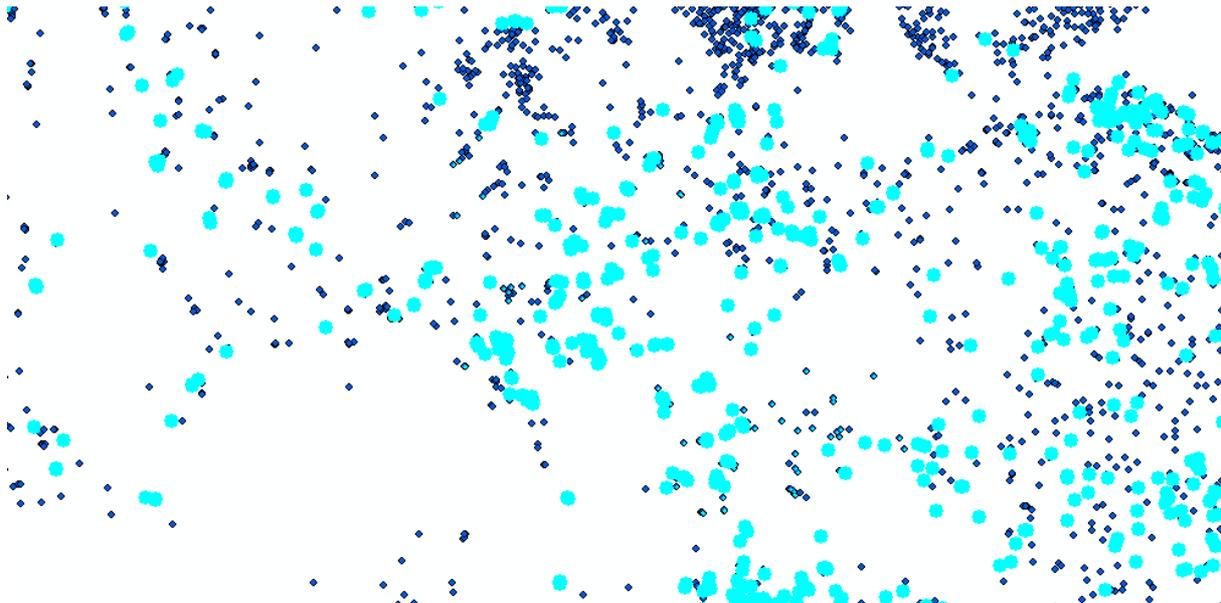
The *Select By Attributes* window can be accessed in the view using the *Selection-Select By Attributes...* menu or in the table using the *Options-Select By Attributes...* menu.



Windows are almost the same but if access is from the view, it will be a drop-down list to pick-up the layer name to select.

The method has to be selected (see 2.1.1 *selection methods*). Usually, the selection is a new one so the method by default is *Create a new selection*. To construct a query, a field must be selected by a *double-click*, followed by an operator and a value. The value can be type directly in the query box or gotten from the value list using the *Get Unique Values* button (list of unique values extracted from the selected field). The query is executed using the *OK* button. Elements corresponding to the query will be highlighted.





Selected Attributes of Well

OBJECTID *	SHAPE *	HydroID *	HydroCode	Longitude	Latitude	LandElev	WellDate	WellDepth	WellState	WellType	AquiferID
335	Point	335	<Null>	-9999	-9999	-9999	1994-05-19	54.9	Dry		<Null>
341	Point	341	<Null>	-9999	-9999	-9999	1994-01-15	56.9	Dry		<Null>
344	Point	344	<Null>	-9999	-9999	-9999	1993-12-11	54.9	Dry		<Null>
345	Point	345	<Null>	-9999	-9999	-9999	1993-12-11	54.9	Dry		<Null>
346	Point	346	<Null>	-9999	-9999	-9999	1993-04-22	54.9	Dry		<Null>
349	Point	349	1001B4H010D01	-0.085556	10.58111	369	1993-12-12	-9999	Dry		10
353	Point	353	<Null>	-9999	-9999	-9999	1993-12-10	56.4	Dry		<Null>
357	Point	357	1000C1D011D01	0	10.40167	171	1993-12-16	68.6	Dry		10
359	Point	359	<Null>	-9999	-9999	-9999	1993-12-11	-9999	Dry		<Null>
10	Point	10	<Null>	-9999	-9999	-9999	1995-05-18	52	Dry		<Null>
21	Point	21	<Null>	-9999	-9999	-9999	1992-04-30	25	Dry		<Null>
22	Point	22	<Null>	0000	0000	0000	1992-04-30	25	Dry		<Null>

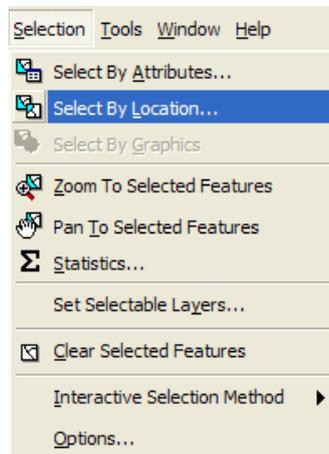
Record: 1 | Show: All Selected | Records (2937 out of 10110 Selected) | Options

A query can be simple or complex using logical operator. For more information about query, see *about building an SQL expression* in the *ArcGIS Help*.

2.1.4 Spatial selection

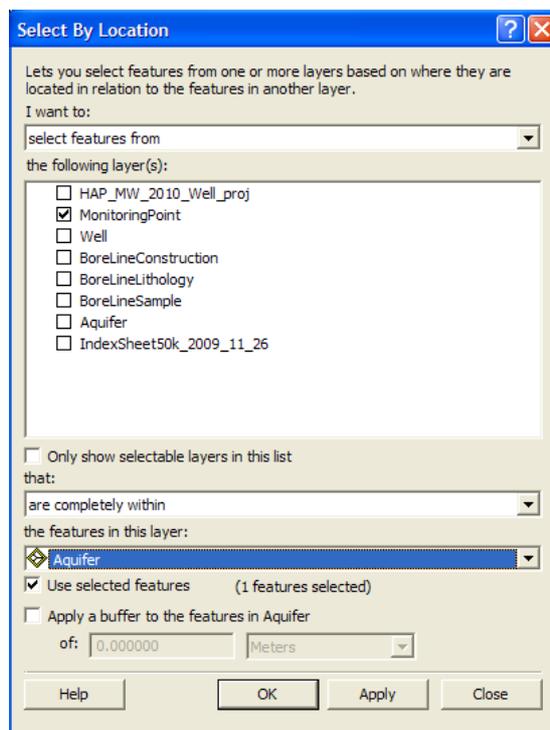
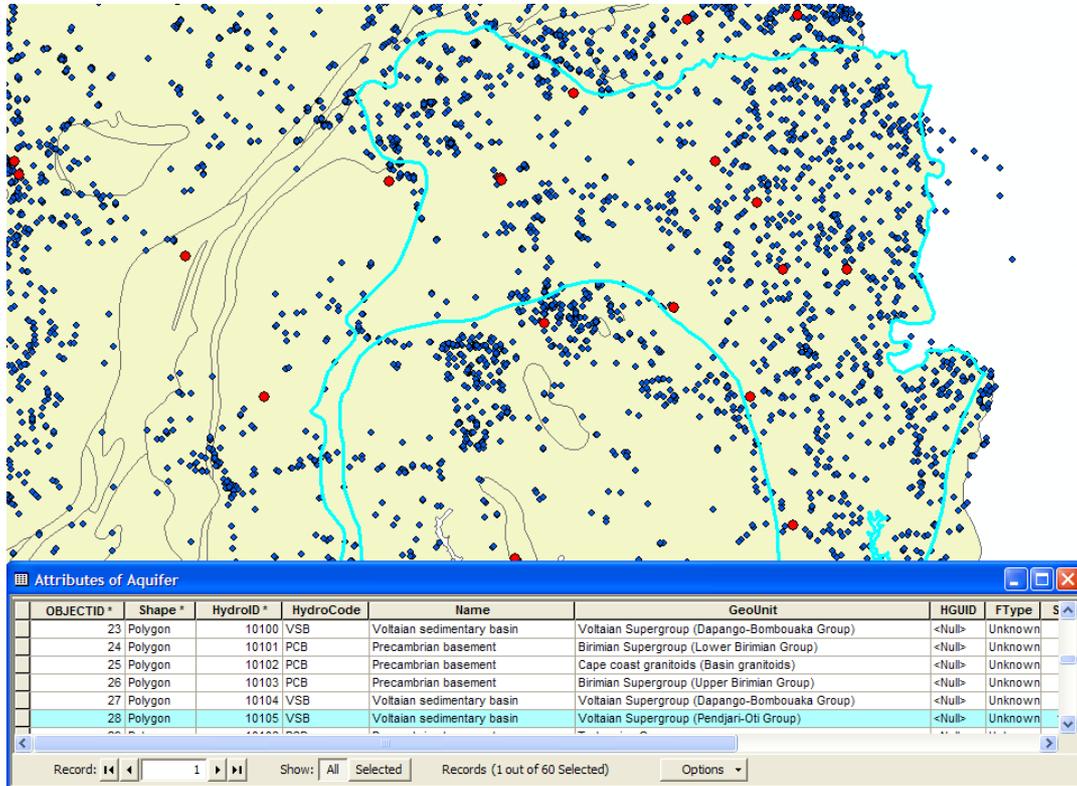
The spatial selection is based on the object location and that is why it can be realized only with a features class.

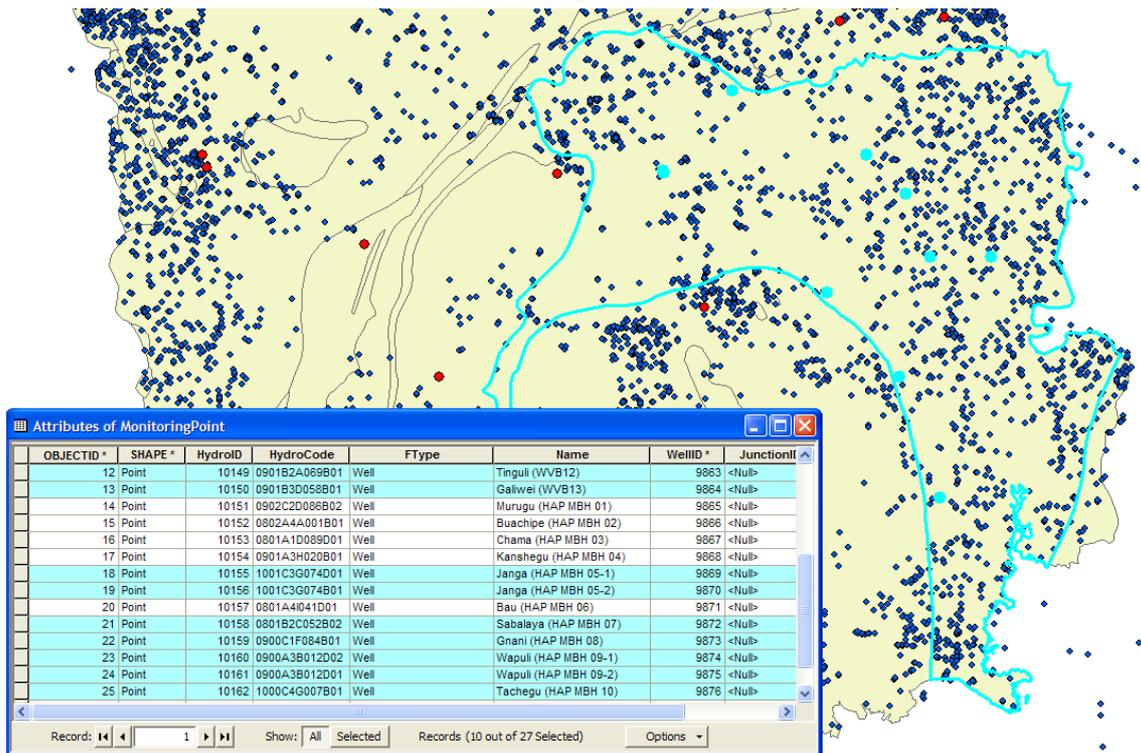
The *Select By Location* window can be accessed using the *Selection-Select By Location...* menu.



The method has to be selected (see 2.1.1 *selection methods*). Usually, the selection is a new one so the method by default is *Select features from*. To construct a spatial query, the layer

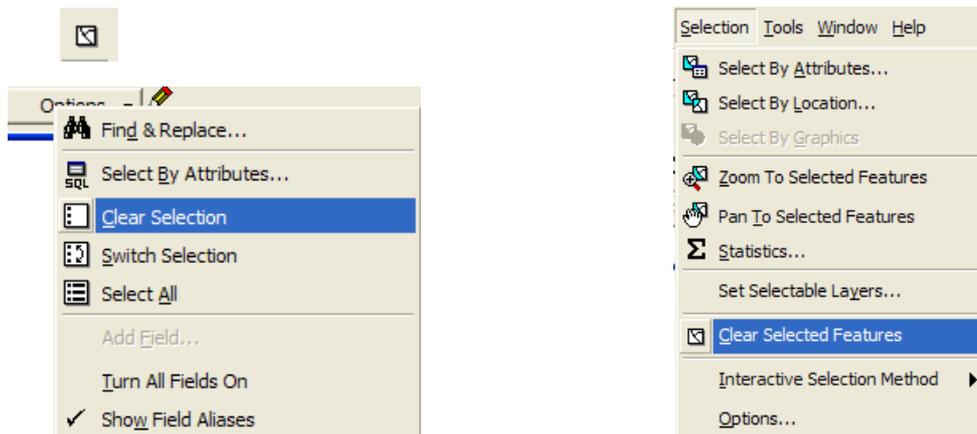
to select must be checked first (one or many). Next, the spatial relationship (for more information about spatial relationship, see *Select By Location* in the *ArcGIS Help*) and the reference layer have to be selected. If the selection is performed regarding a particular entity in the reference layer, this entity must be selected first and the *Use selected features* option must be checked. Otherwise, all reference layer features will be used. The spatial query is executed using the *OK* button. Elements corresponding to the query will be highlighted.



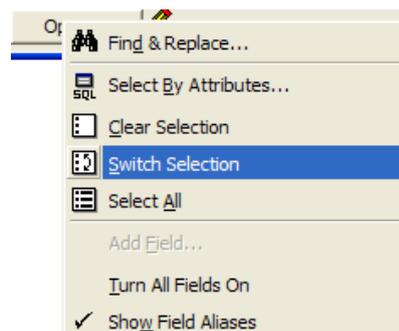


2.1.5 Clear selection, select all and switch selection

The selection can be cleared (no record selected) in the table using the *Options-Clear Selection* menu or in the view, if it is a features table, with the *Clear Selected Features* button or the *Selection-Clear Selected Features* menu. Clearing the selection in a view will unselected all selected features in the view.

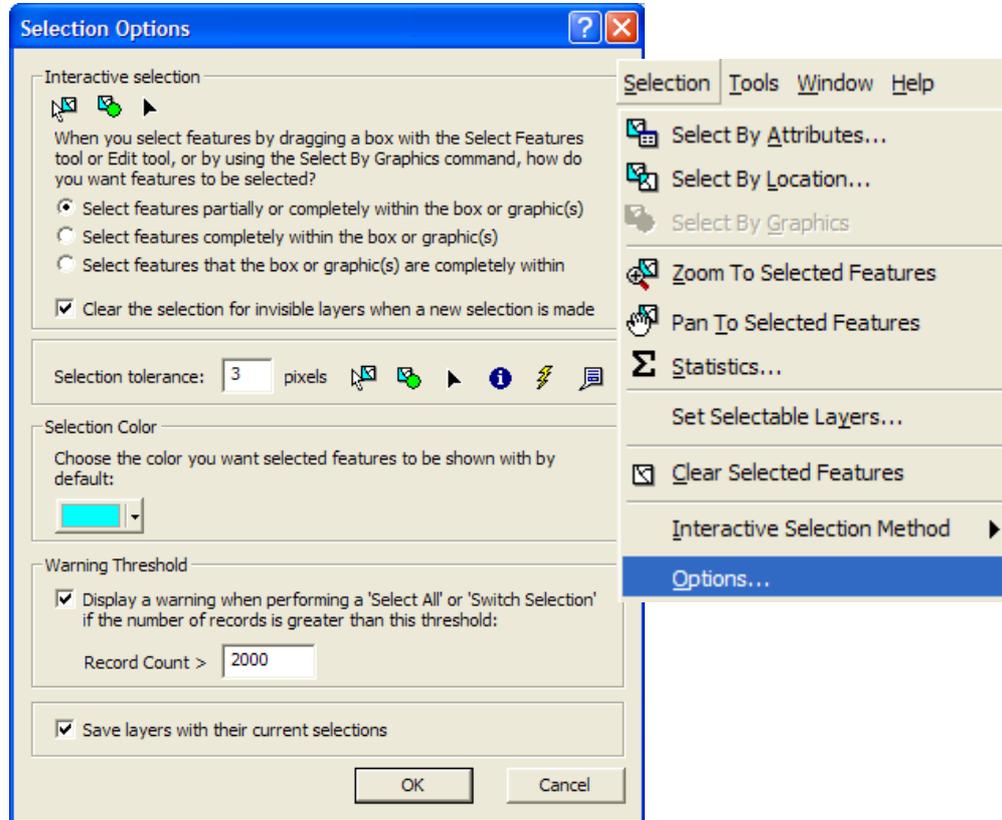


In the table, the selection can also be switched using the *Options-Switch Selection* menu. Selected records become unselected and unselected records become selected.



2.1.6 Manage selection options

In the view, using the *Selection-Options* menu, options regarding selection could be modified.

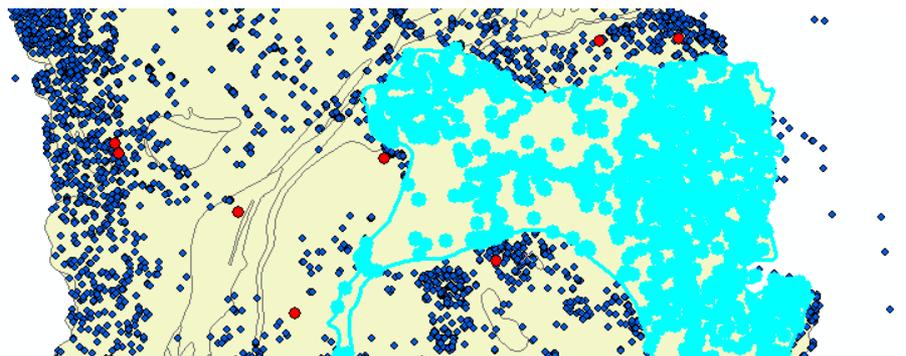
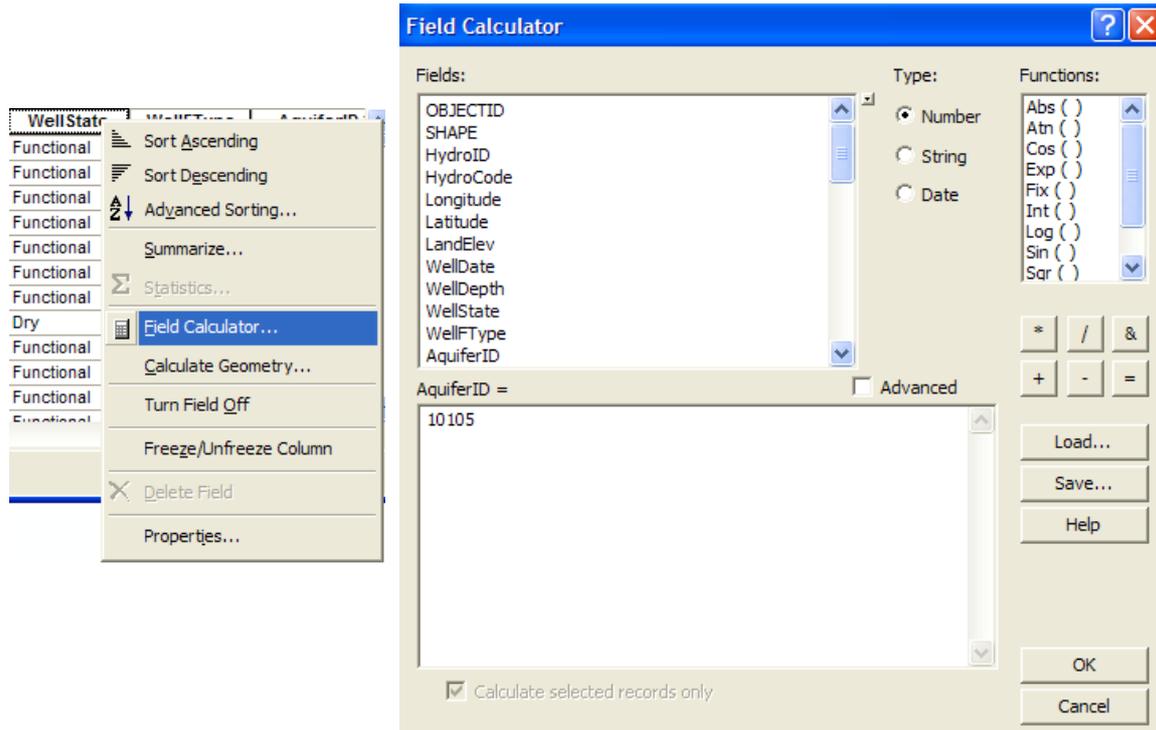


2.2 Use the Calculator tool

The *Calculator* tool is used in the table to populate fields using a formula. The formula could be a simple value like for example "1", the sum of values from two fields, a functions or a complex query to extract information from a string, for example the index number of the *HydroCode* (10 first characters). The Calculator tool could be used inside or outside an edit session. If the edit session is started, the *undo/redo* operation can be used. Otherwise, the treatment is irreversible.

The *Field Calculator* window can be accessed using a *right-click* on the title field to populate and by selecting *Field Calculator...* menu.

A value or a formula must be placed in the box. The result will populated all the table records or only selected ones if there is a selection.



Selected Attributes of Well

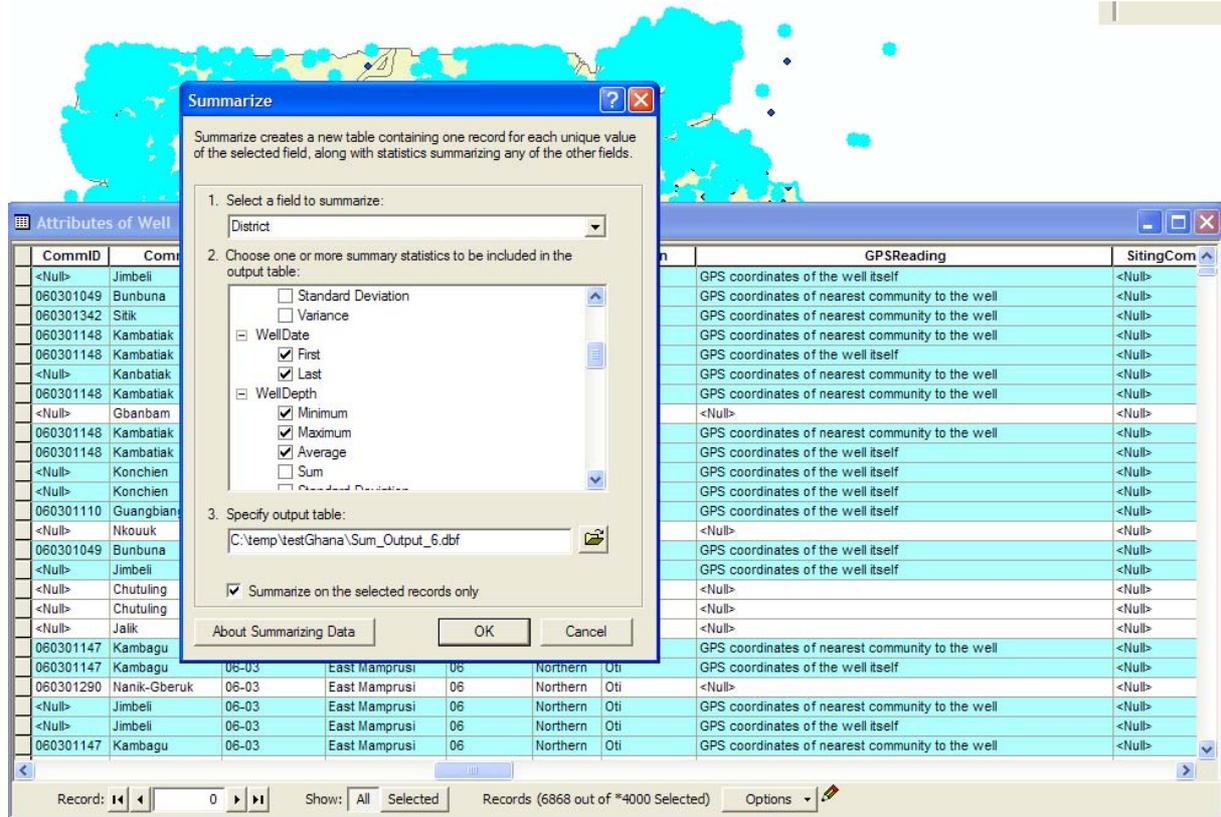
WellState	WellFType	AquiferID *	AqCode	HGUGeneral	GeoUnit	CommID
Dry		10105	VSB	<Null>	Voltaian Supergroup (Pendjari-Oti Group)	060301333
Functional		10105	VSB	<Null>	Voltaian Supergroup (Pendjari-Oti Group)	<Null>
Functional		10105	VSB	<Null>	Voltaian Supergroup (Pendjari-Oti Group)	<Null>
Functional		10105	VSB	<Null>	Voltaian Supergroup (Pendjari-Oti Group)	061001064
Dry		10105	VSB	<Null>	Voltaian Supergroup (Pendjari-Oti Group)	061001212
Dry		10105	VSB	<Null>	Voltaian Supergroup (Pendjari-Oti Group)	061001212
Dry		10105	VSB	<Null>	Voltaian Supergroup (Pendjari-Oti Group)	061001212
Functional		10105	VSB	<Null>	Voltaian Supergroup (Pendjari-Oti Group)	<Null>
Dry		10105	VSB	<Null>	Voltaian Supergroup (Pendjari-Oti Group)	061001212
Functional		10105	<Null>	<Null>	<Null>	<Null>
Functional		10105	VSB	<Null>	Voltaian Supergroup (Pendjari-Oti Group)	<Null>
Functional		10105	VSB	<Null>	Voltaian Supergroup (Pendjari-Oti Group)	061101122

Record: 0 Show: All Selected Records (2014 out of *2000 Selected) Options

2.3 Use the Summarize tool

The *Summarize* tool allows calculating statistics by regrouping elements of the same value. Statistics are the count, first, last, sum, average, minimum, maximum, standard deviation and variance value.

The *Summarize* window can be accessed using a *right-click* on the title field to query and by selecting *Summarize...* menu.



The field to summarize is the one the system will use to regroup information and calculate statistics.

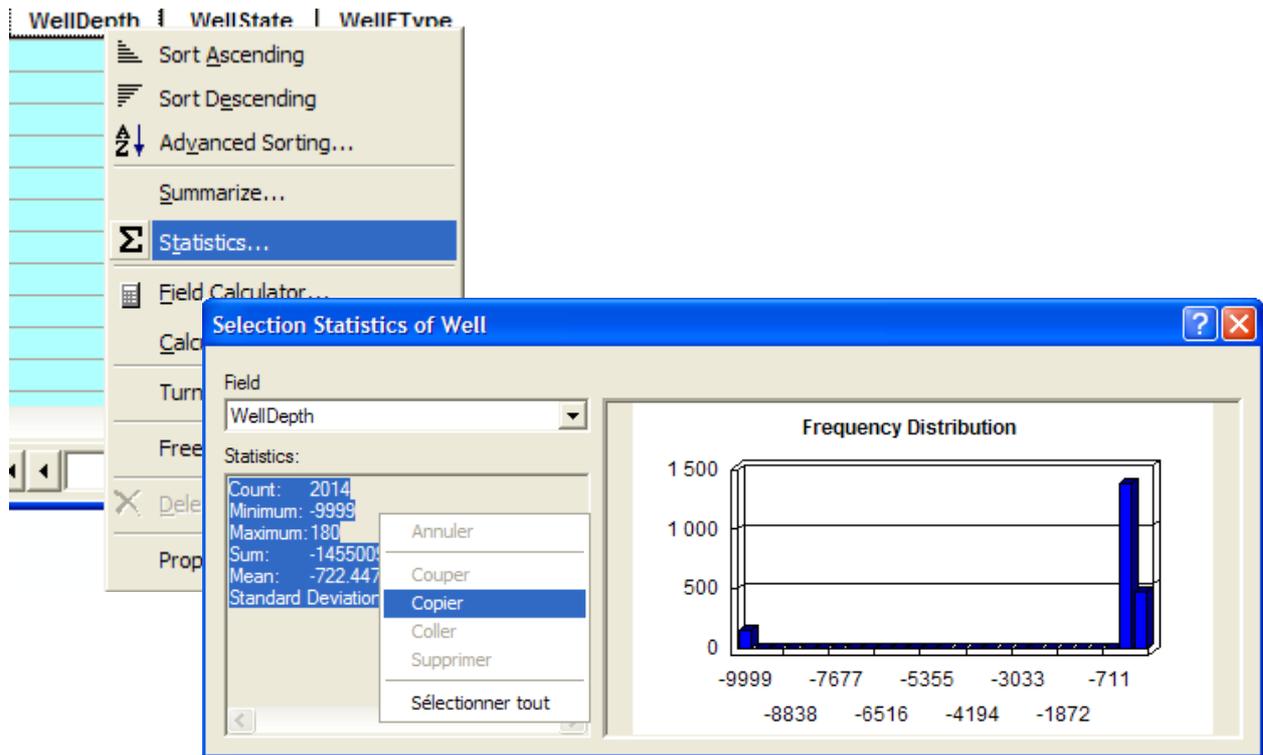
By default, the *Summarize on the selected records only* option is checked and only selected records are used in the process. The result will be presented in a new external table containing the summary statistics. The *Count* field is always calculated and there is one column for each summary statistics checked in the list.

OID	District	Count_District	Average_LandElev	First_WellDate	Last_WellDate	Minimum_WellDepth	Maximum_WellDepth	Average_WellDepth
0		0	-9999	1987-11-16	1993-04-21	25	61	38.35
1	Bawku East	727	29.425	1924-10-17	2007-04-01	-9999	99.38	-8549.8385
2	Bawku West	211	-1719.5403	1956-01-23	2000-05-25	-9999	46	-9238.8582
3	Bole	348	-521.7126	1983-12-31	2006-04-02	20	99	47.9542
4	Bolgatanga	409	-618.335	1956-09-03	2005-06-20	-9999	90	-8453.0587
5	Bongo	241	-1430.4315	1956-06-12	6748-11-26	-9999	90	-8041.8925
6	Builsa	188	-87.4149	1956-06-27	1999-06-08	-9999	62	-8504.049
7	East Gonja	295	-3940.6983	1985-12-31	2028-04-05	-9999	93	-3393.063
8	East Mamprusi	374	-976.1845	1976-07-05	2007-07-31	-9999	166	-3736.5863
9	Gushiegu Karaga	252	-1517.7659	1973-11-02	2019-11-03	-9999	99	-194.0384
10	Jirapa Lambussie	348	-390	1955-12-10	2003-08-16	-9999	69	-7633.6911
11	Kassena Nankana	365	-687.5452	1956-06-28	2005-06-19	-9999	88	-7002.0028
12	Lawra	311	-5045.672	1976-02-08	2003-07-01	-9999	73	-7481.0518
13	Nadowli	306	-178.8235	1954-08-01	2002-06-29	-9999	68	-6915.7199
14	Nanumba	167	-2335.018	1985-06-29	2007-07-07	-9999	121	-74.2807
15	Saboba Chereponi	203	-1146.1724	1960-04-16	2007-07-15	-9999	121	-155.2193
16	Savelugu Nanton	126	-497.6508	1973-11-02	2007-08-04	-9999	155	-31.4906
17	Sissala	241	9.195	1956-05-26	2005-07-08	-9999	104	-7750.2826
18	Tamale	12	-9999	1993-02-10	1993-02-10	12.1	61	41.3917
19	Tolon Kumbungu	64	-488.0781	1973-11-02	2006-06-07	25	96	44.3969

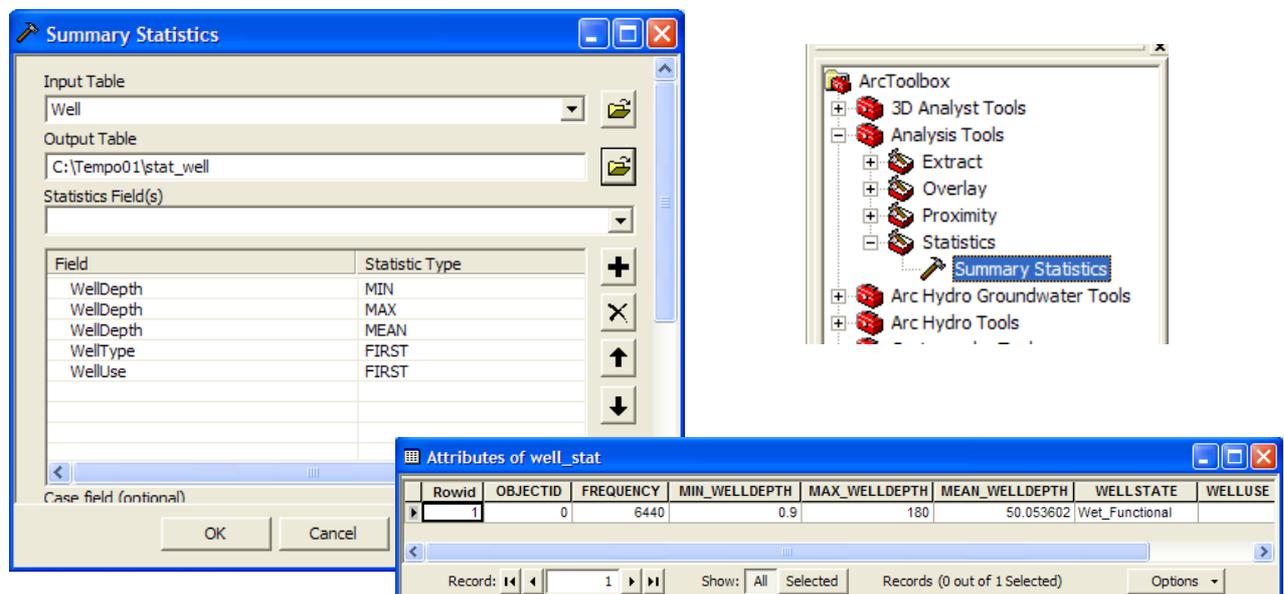
2.4 Obtain statistics

It is possible to obtain statistics by a *right-click* on the title field to query and by selecting *Statistics...* menu. The field must be in numeric format.

All records in the table will be used for the statistic calculation or only selected ones if there is a selection. Results will be presented in a popup window. They could be *copy-paste* in a text document using a *right-click* and *Copy* menu.

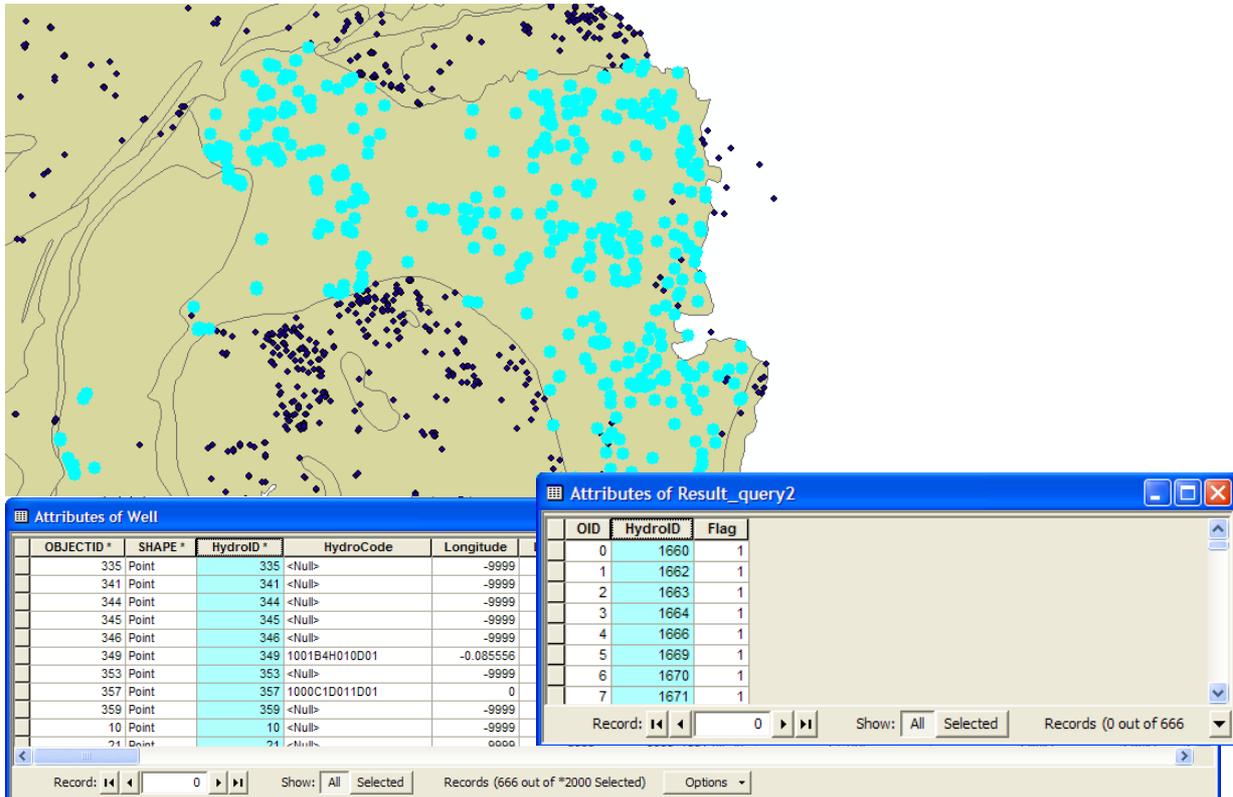


ArcToolBox provide also the tool *Summary Statistics*. It allows the calculation of statistics for any fields present in the input table. Results will be presented in an output table.

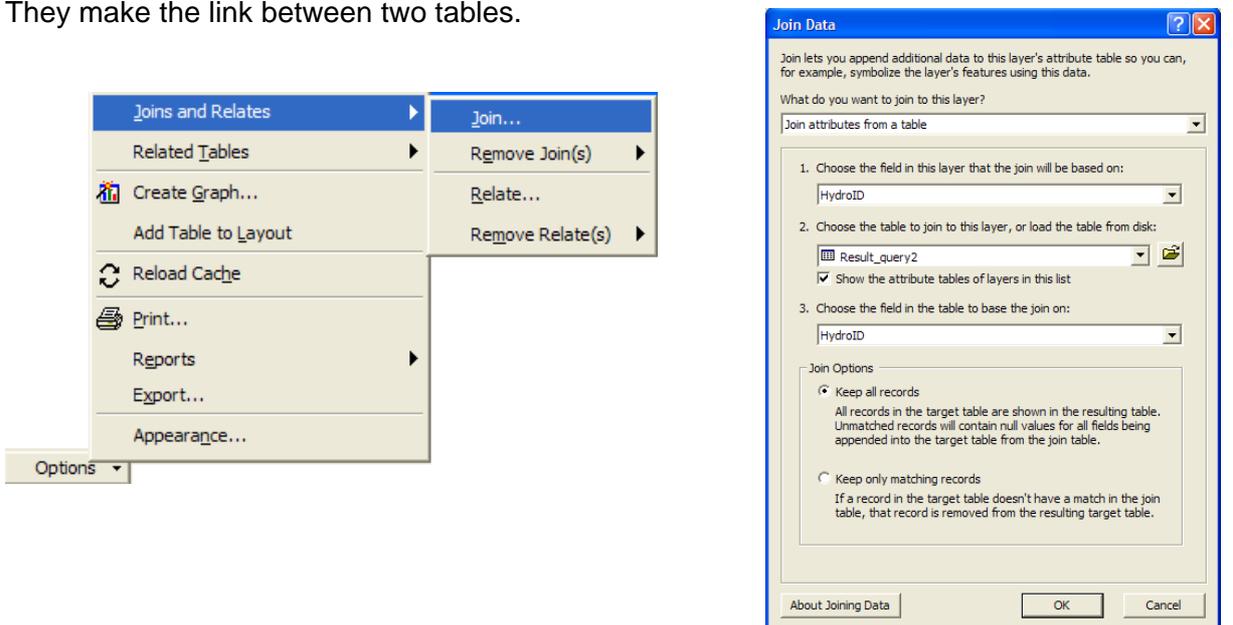


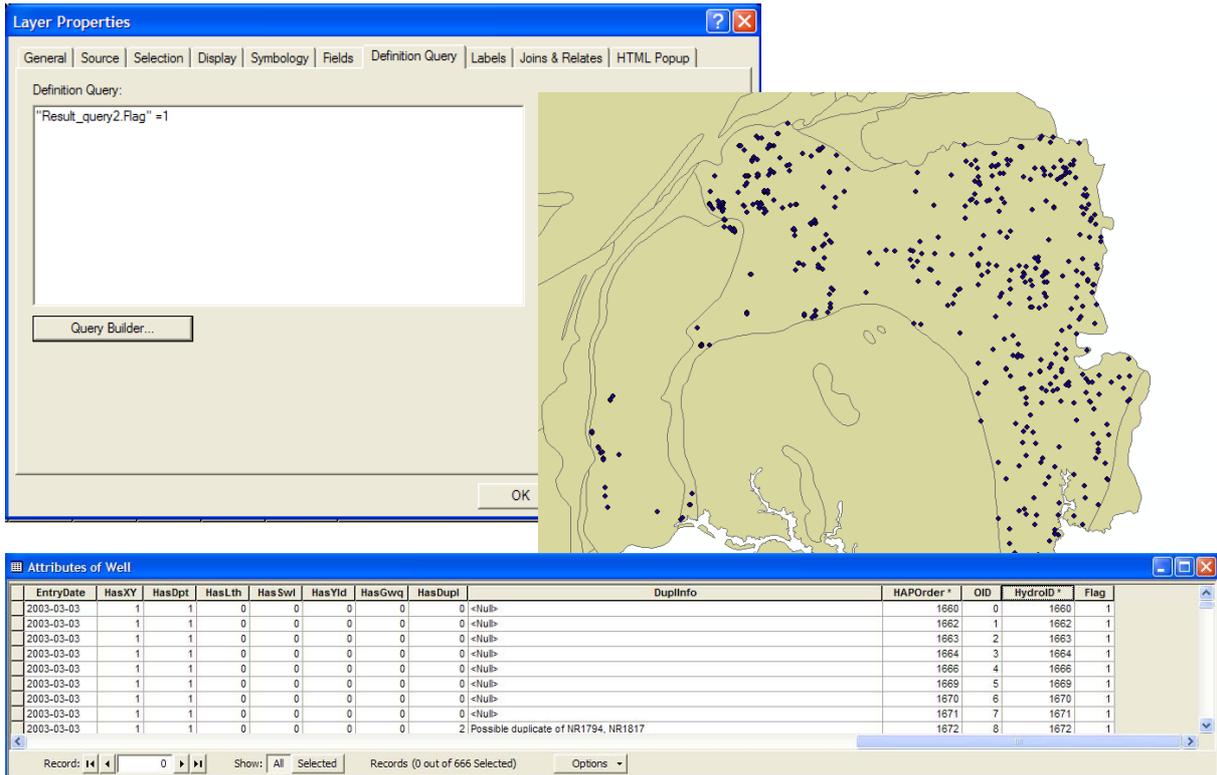
2.5 Using a table join and relate

An external table can be used to add information to a main table. In the WRC ground water database, the model structure is fixed and fields cannot be added. So joining an external table is a good option to show, for example, the result of a request saves in a field. Once the join is executed, it is easy to reselect features corresponding to the query or simply used the field to apply a filter on the layer.



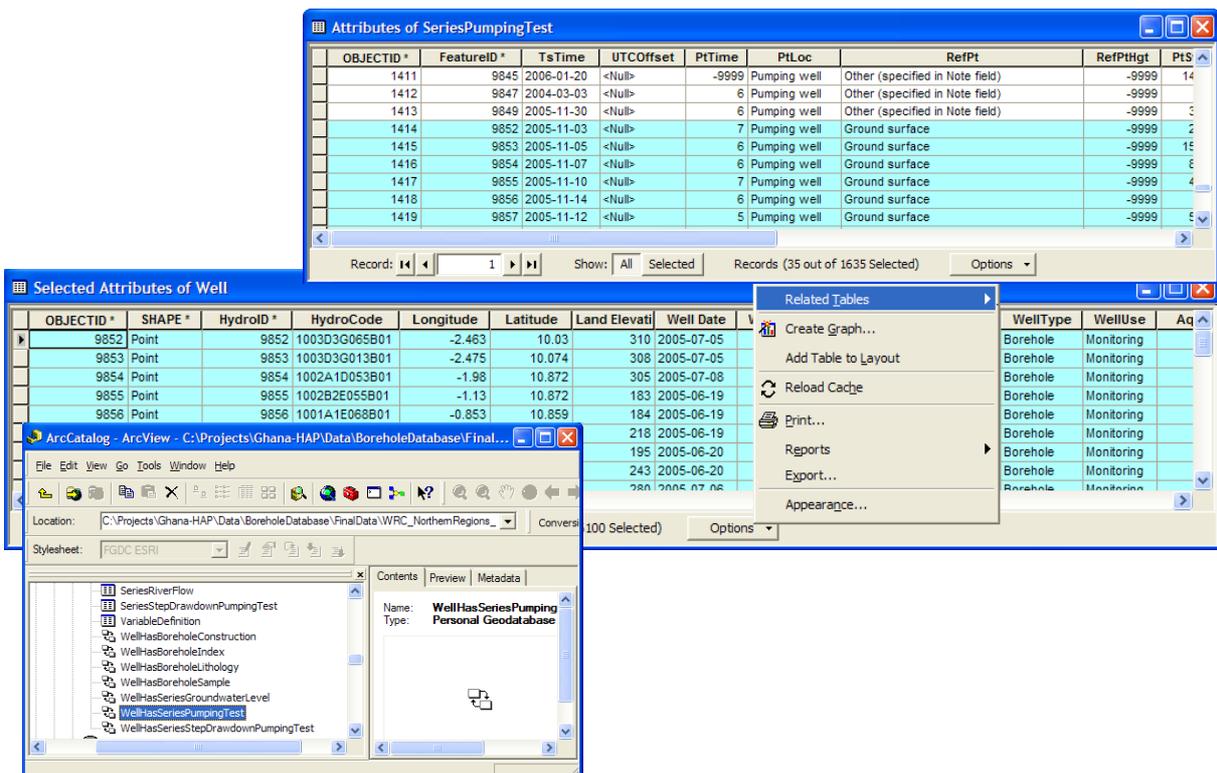
The joint operation can be realized in the main table using the *Options-Joins and Relates-Join...* menu. In this case, external and destination key fields are both *HydroID*. External key is the field from the table to join and destination key is the field that the join will be based on. They make the link between two tables.





A *Relate* can also be set to link to table together. Visually, tables are independent but if a selection is applied on a table, corresponding records will be selected when the relation is selected in the *Options-Related Tables* menu.

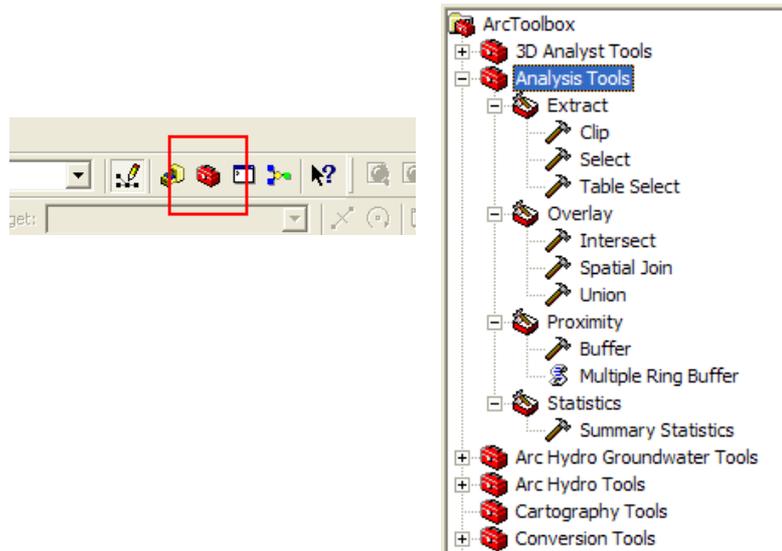
The *ArcHydro Grounwater* model use many relates to link, for example, *Timeseries* tables. Those relations have been preset in ArcCatalog and are a part of the geodatabase.



2.6 Spatial Analysis Tools

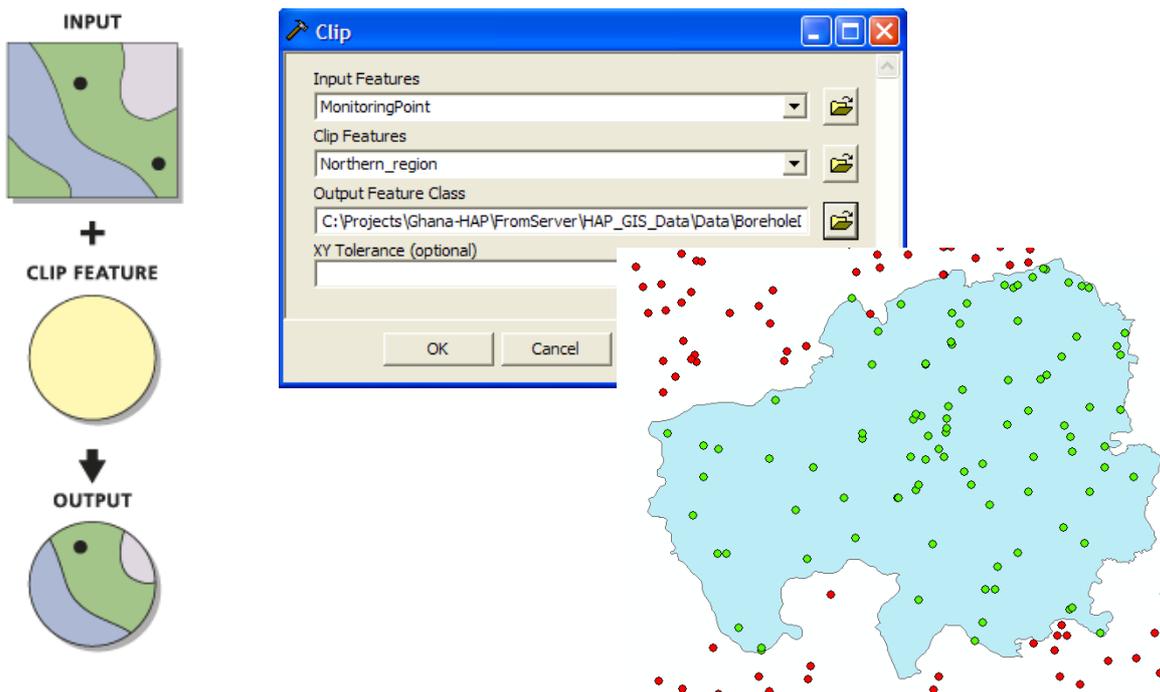
In *Arctoolbox*, many tools are available for spatial analysis.

Those tools are available in the *Analysis Tools* toolbox. They are presented in four groups: *Extract*, *Overlay*, *Proximity* and *Statistics*.

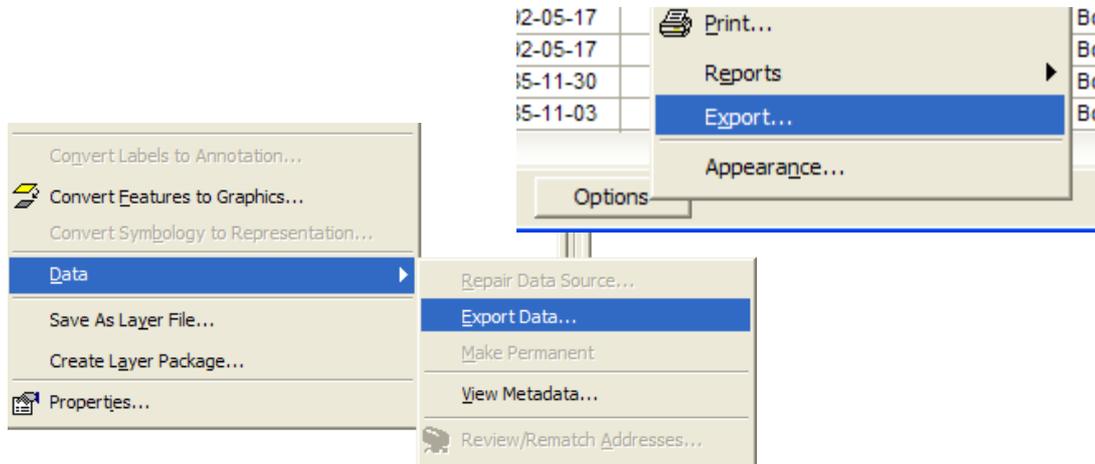


2.6.1 Extract group

This group has three tools. The first one, *Clip*, allows extracting input features that overlay the clip features. For example, as input features *MonitoringPoint* layer, as clip features the *Northern_region* layer, and as a result layer, monitoring points included by the northern region polygon. Result layer will always contains the same type of features than the input layer and clip layer is always polygon type.

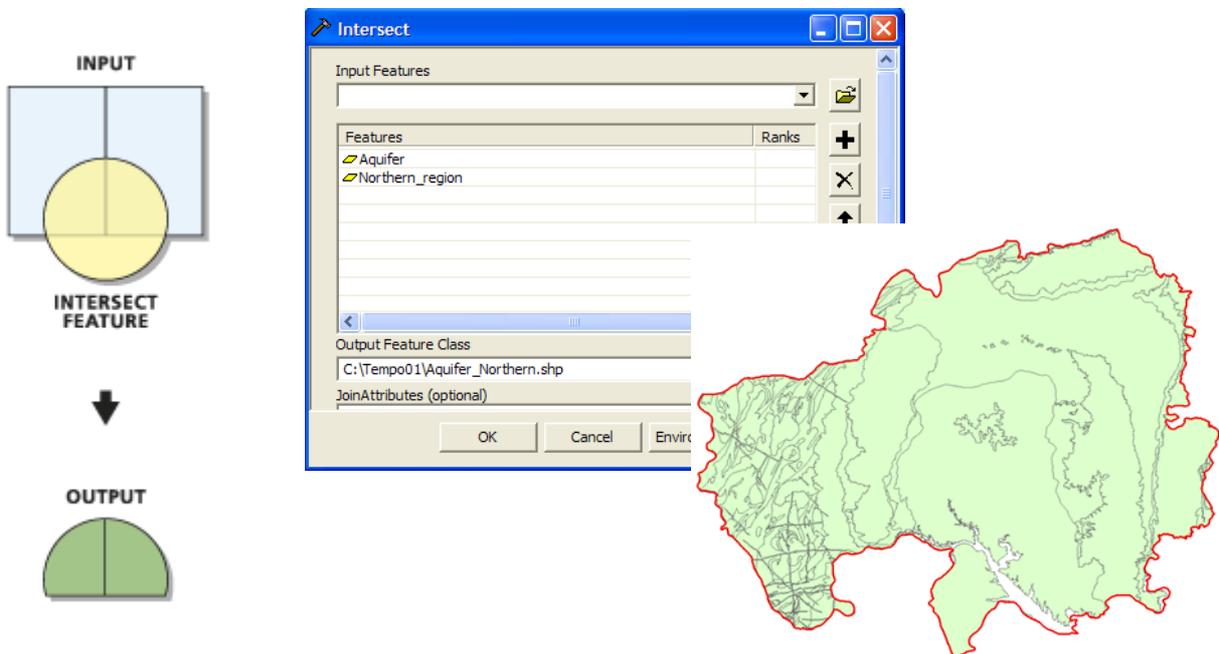


The two other tools present the same results than the *Data-Export Data...* menu (*right-click* on a layer in the *Table of Contents*) for features extraction from a layer and *Options-Export...* menu for records extraction from a table.

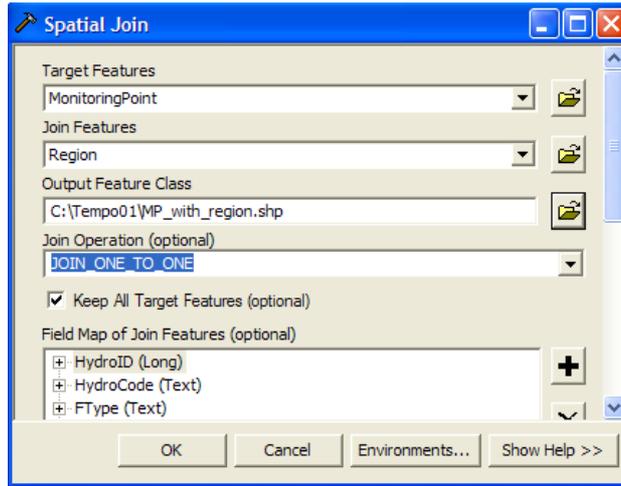


2.6.2 Overlay group

The second group has three tools. The first one, *Intersect*, allows computing a geometric intersection of the input feature. Features or portions of features which overlap in all layers and/or feature classes will be written to the output feature class. For example, as input features *Aquifer* layer and the *Northern_region* layer, and as a result layer, aquifer cut by the northern region polygon with attributes of two input layers.

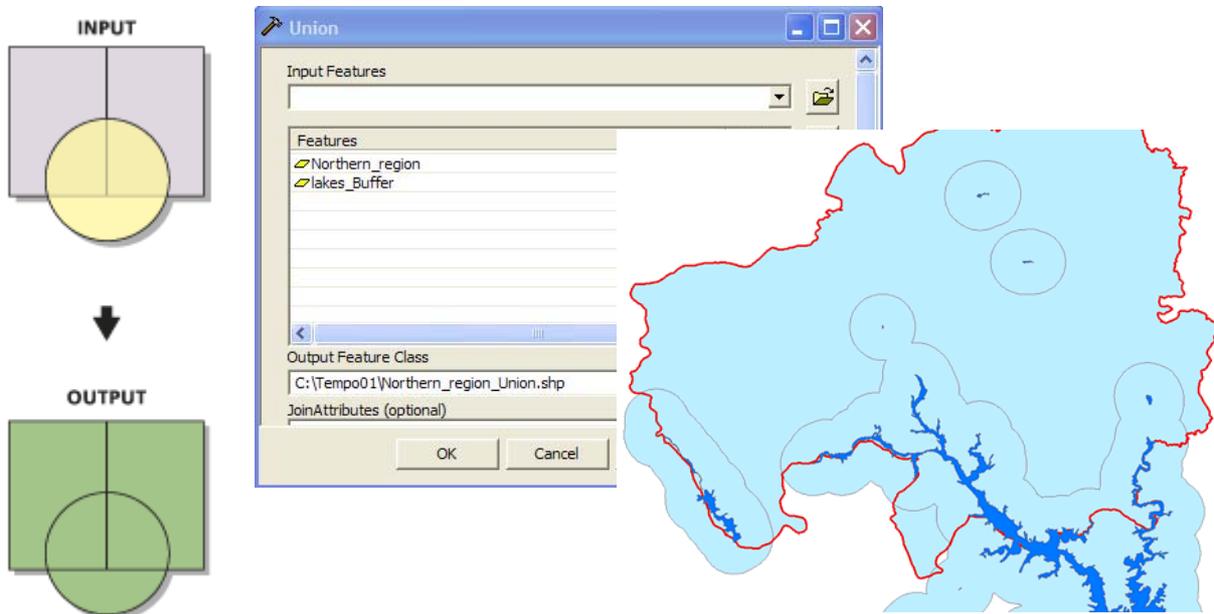


The second one, *Spatial join*, allows the creation of a table join in which fields from one layer's attribute table are appended to another layer's attribute table based on the relative location of the features in the two layers. For example, as target features *MonitoringPoint* layer, as join features *Region* layer, and as a result layer, monitoring points with additional fields from the region where the monitoring point is located. Result layer will always contain the same type of features than the input layer.



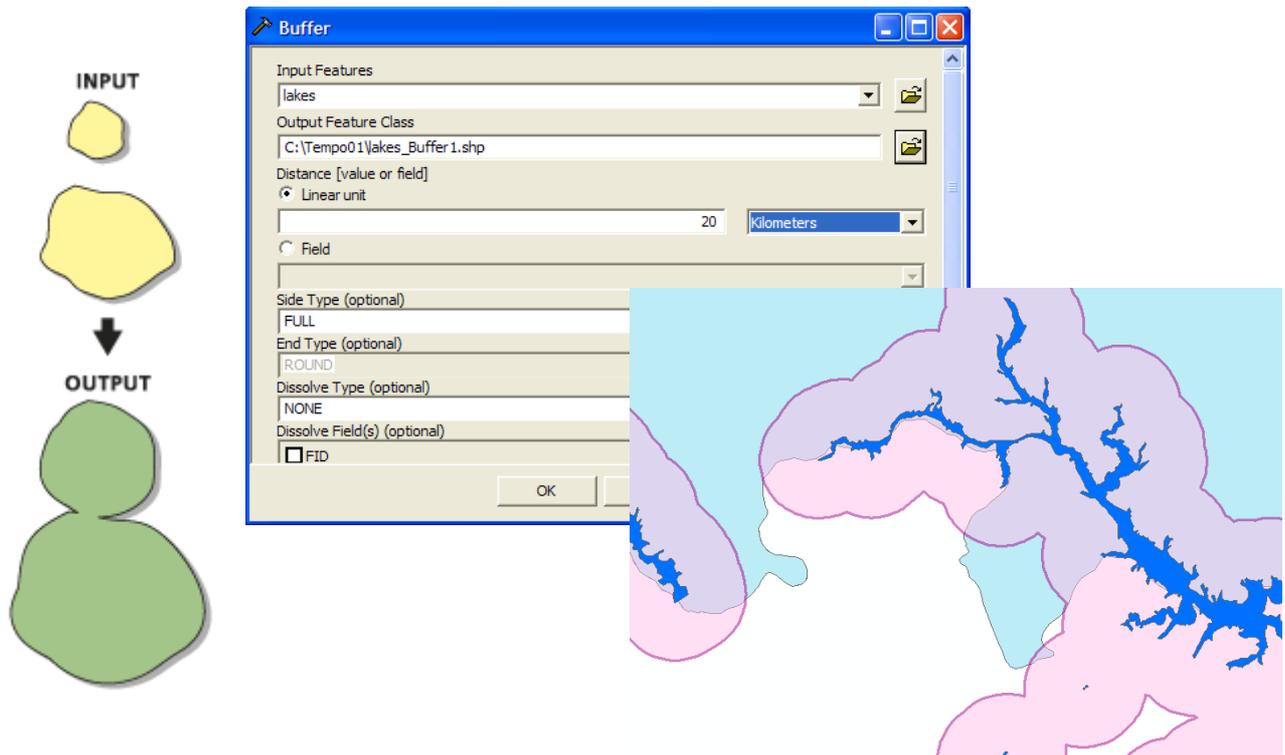
FID	Shape*	Join_Count	HydroID	HydroCode	FType	Name	WellID	JunctionID	AREA	PERIMETER	NAME_1	CAPITAL	POP84	POP86	POP88	POP2K	POP
0	Point	1	10136	100303905001	Well	WVB01 (Wa)	905	0	1.52564	5.00101	Upper West	Wa	438000	502822	564103	632052	632052
1	Point	1	10137	1003030013801	Well	WVB02 (Wa)	988	0	1.53564	5.88101	Upper West	Wa	438008	502822	564103	632852	632852
2	Point	1	10138	1002A10053801	Well	WVB03 (Tumu)	565	0	1.53564	5.86101	Upper West	Wa	438008	502822	564103	632852	632852
3	Point	1	10139	100202L055801	Well	WVB04 (Bona)	905	0	0.7079	5.04409	Upper East	Bolgatanga	772744	903320	1020726	1171543	1171543
4	Point	1	10140	1001A1E988801	Well	WVB05 (Gowrie Tigrre)	988	0	0.7079	5.04409	Upper East	Bolgatanga	772744	903320	1020726	1171543	1171543
5	Point	1	10141	1001A1F004801	Well	WVB06 (Bongo-Nayre)	565	0	0.7079	5.04409	Upper East	Bolgatanga	772744	903320	1020726	1171543	1171543
6	Point	1	10142	1001A48053001	Well	WVB07 (Dakoko)	905	0	0.7079	5.04409	Upper East	Bolgatanga	772744	903320	1020726	1171543	1171543
7	Point	1	10143	1101N10510801	Well	WVB08 (Rakoko)	888	0	0.7079	5.04409	Upper East	Rokstadana	772744	903320	1020726	1171543	1171543

The third one, *Union*, allows computing a geometric intersection of the input feature. All features will be written to the output feature class with the attributes from the input features, which it overlaps. For example, as input features *Lake_Buffer* layer (20km buffer) and the *Northern_region* layer, and as a result layer, lake 20km buffer merge with northern region polygon with attributes of two input layers.

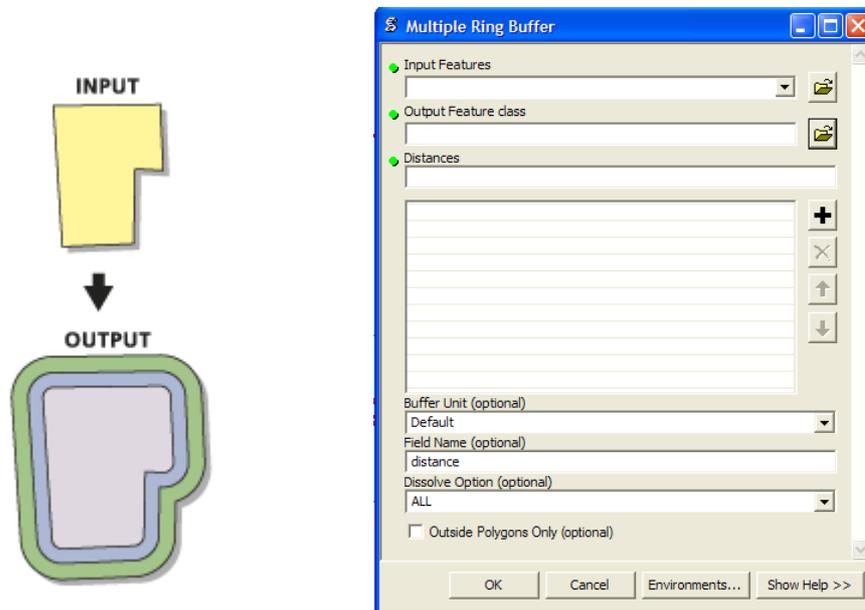


2.6.3 Proximity group

The third group has two tools. The first one, *Buffer*, allows the creation of a buffer polygon to a specified distance around the input features. An optional dissolve can be performed to remove overlapping buffers. For example, as input features *Lake* layer and as a result layer, a polygon layer composed of a 20 km buffer.



The second tool, *Multiple Ring Buffer*, is almost the same. It allows the creation of a new feature class of buffer features using a set of buffer distance. The new features may be dissolved using the distance values, or as a set of individual features.



2.6.4 Statistics group

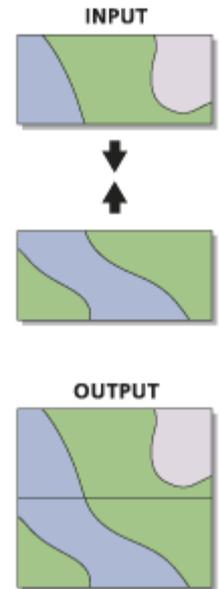
The *Statistics* group present only one tool: Summary Statistics. This tool has been presented in the section 2.4 *Obtain statistics*.

2.6.5 Merge and Dissolve tools

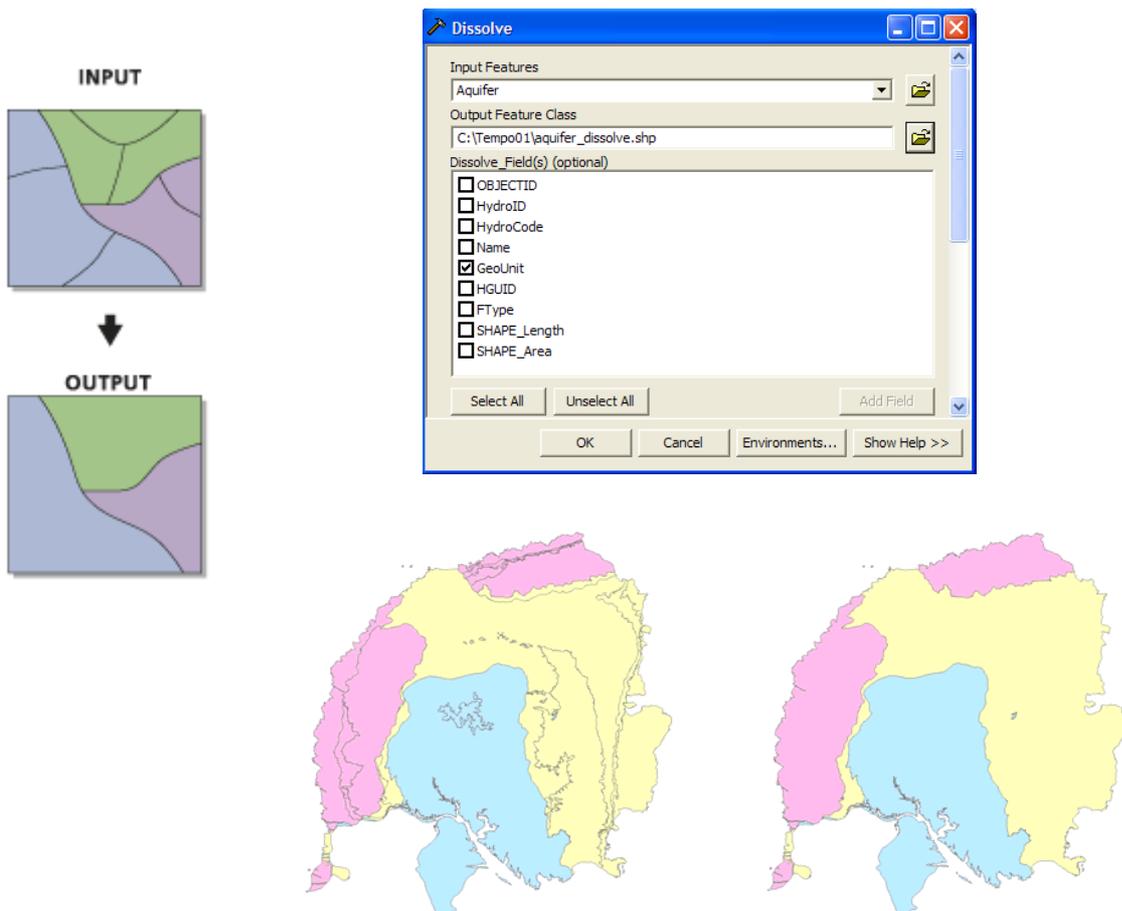
Two other tools are very useful but are not included in the *Analysis Tools* toolbox: *Merge* and *Dissolve*.

The *Merge* tool allows combination of input features from multiple input source (of the same data type) into a single, new, output feature class. The input data may be point, line or polygon feature classes.

For example, if *MonitoringPoint* layer are classified by region and are stored in different shapefiles, they could be merged to get a unique layer.



The *Dissolve* tool allows to aggregate features based on specified attributes. For example, a dissolve could be applied on the *Aquifer* layer to get geounits.



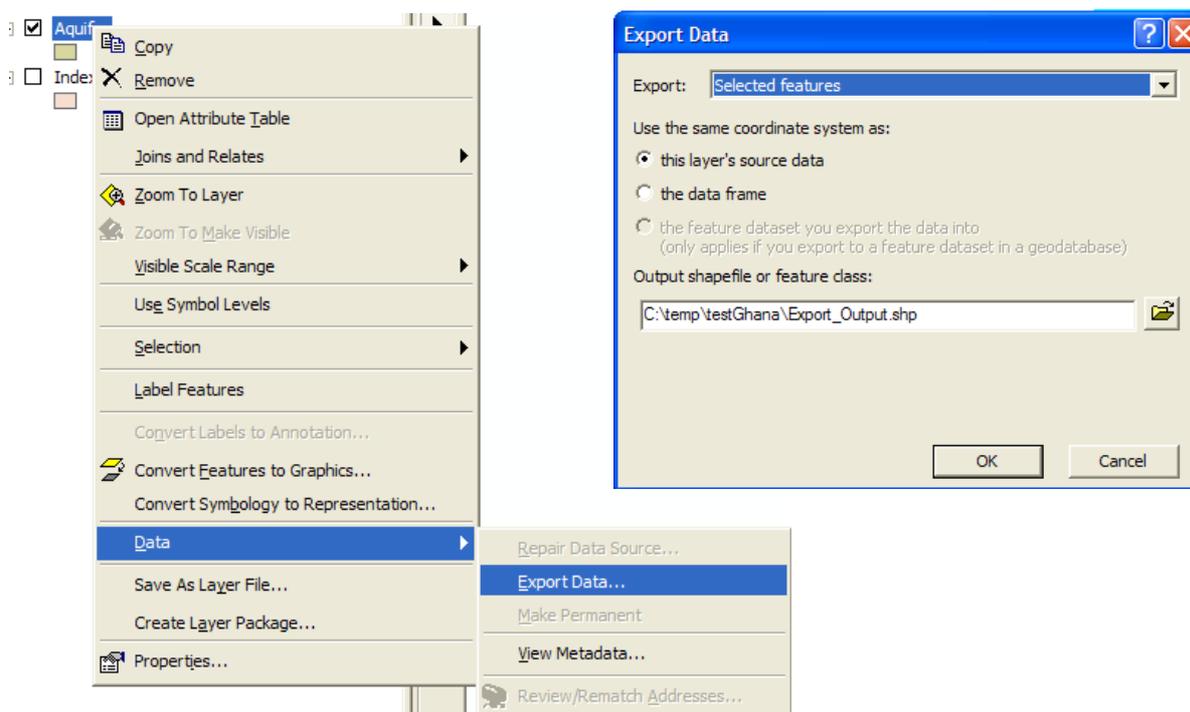
3. EXTRACTING AND PRESENTING INFORMATION

Data analysis gives answers to questions. That information can be extracted, reported, graphed or mapped to be published.

3.1 Export data

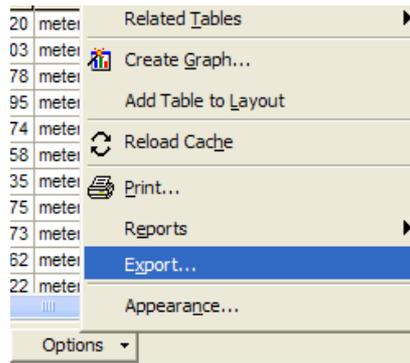
Data could be exported from the database. If there is an existing selection, only selected elements will be exported. If there are hidden fields, only visible fields will be exported. If an external table is joined to the main table, its attributes will be exported too.

The exportation of a dataset can be realized by a *right-click* on the dataset to export using the *Data-Export Data...* menu.



Dataset export formats are *Shapefile*, *Personnal Geodatabase*, *File Geodatabase* and *SDE*. The output coordinate system used for the exportation could be the same as the source layer or could be the same as the data frame (a layer with a different coordinate system could be loaded in a data frame and the system will automatically transform the layer for visualisation). It can also be the same as the destination layer if the output destination is an existing dataset.

Tables can also be exported using the *Options-Export...* menu. Table export formats are *dBase*, *Delimited text file*, *Info*, *Personnal Geodatabase*, *File Geodatabase* and *SDE*. Please note that *Excel* can open a *dBase* file and a *Delimited text file*.

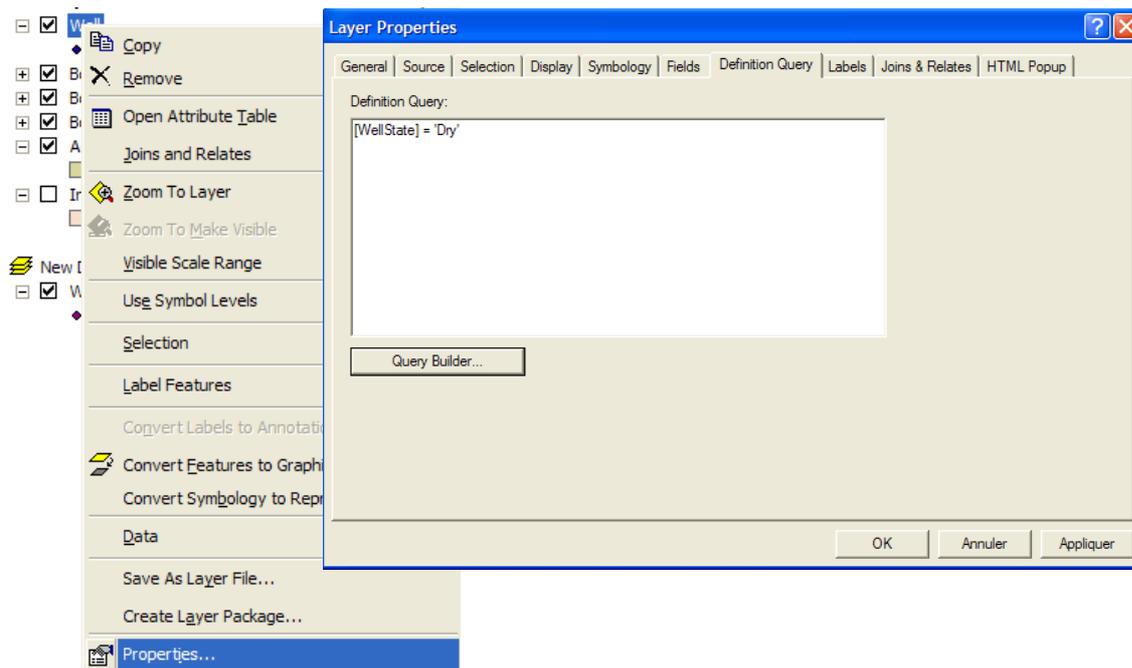


If the exportation is realized for external needs and the destination format is unknown, it is recommended to use the *Shapefile* format because it is a simple and standard format.

3.2 Using a filter

A query is usually used to realize a selection on a table using attributes, but it can also be used as a filter. This can be used for mapping or for analysis to restraint the information presented. The system will present a subset of the original source and all information that does not match with the query will be hidden.

A filter query can be set in the *Layer Properties* window under the *Definition Query* tab.

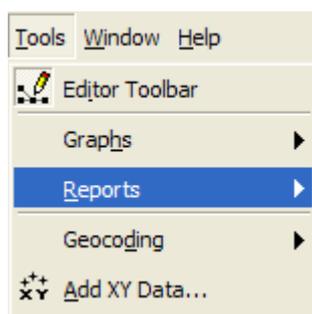




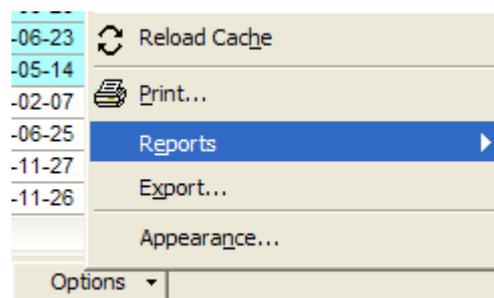
3.3 Creating reports

ArcGIS present two methods for report creation. The first one is possible using an application internal to ArcGIS. This application has been developed for the creation of simple reports. The second method is an external software: *Crystal Report*.

Both are available by using the *Tools-Reports* menu or the *Reports* submenu from the *Options* menu in the table interface.



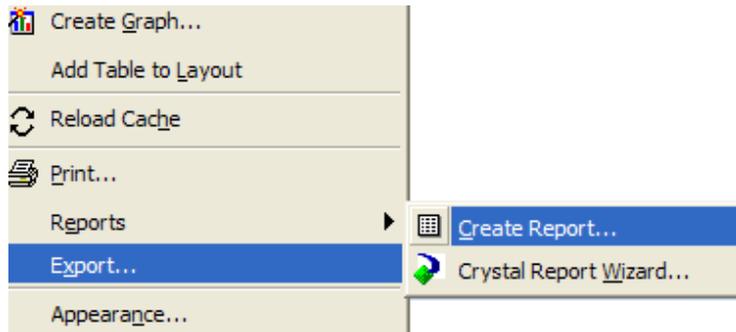
OR



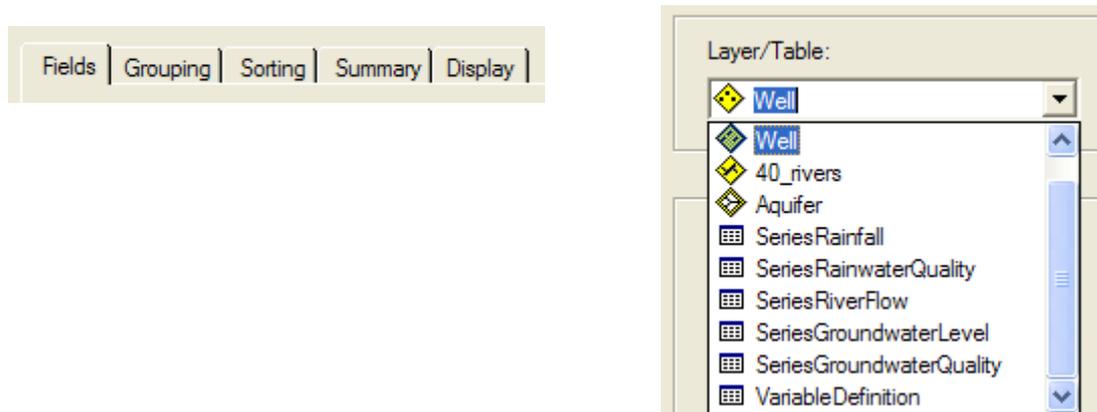
3.3.1 Create a simple report

A report can be created with the internal application using the *Create Report...* menu.

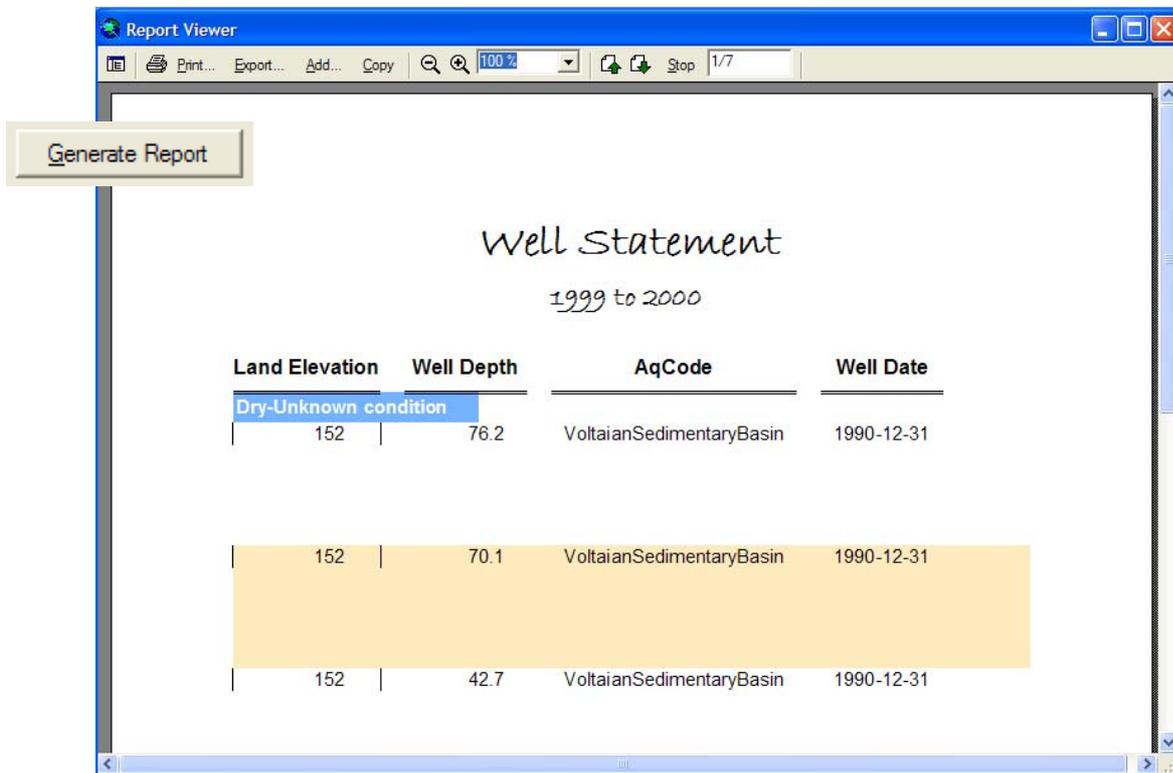
Attention!! If only a subset of information have to be reported, corresponding records have to be selected first.



The *Report Properties* window will open. It presents five tabs: *Fields*, *Grouping*, *Sorting*, *Summary* and *Display*. It is important to select the correct *layer/table* first.



At any moment, the button *Generate Report* could be clicked to visualize in the *Report Viewer* a preview of the report.



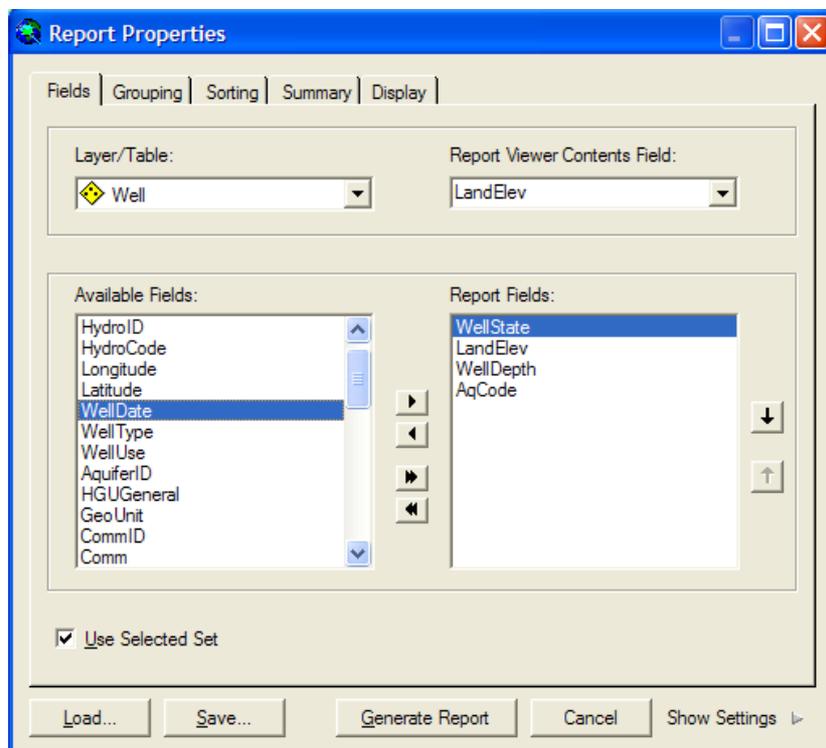
In the *Report Viewer*, the result could be print, export, copy, etc. Result is presented page by page. Up and down arrows allow the visualization of different pages. The field at the end of the button bar shows the number of the active page and the total number of pages in the report.



The report can also be saved (and can be reloaded) using the *Save...* button.

3.3.1.1 *Fields tab*

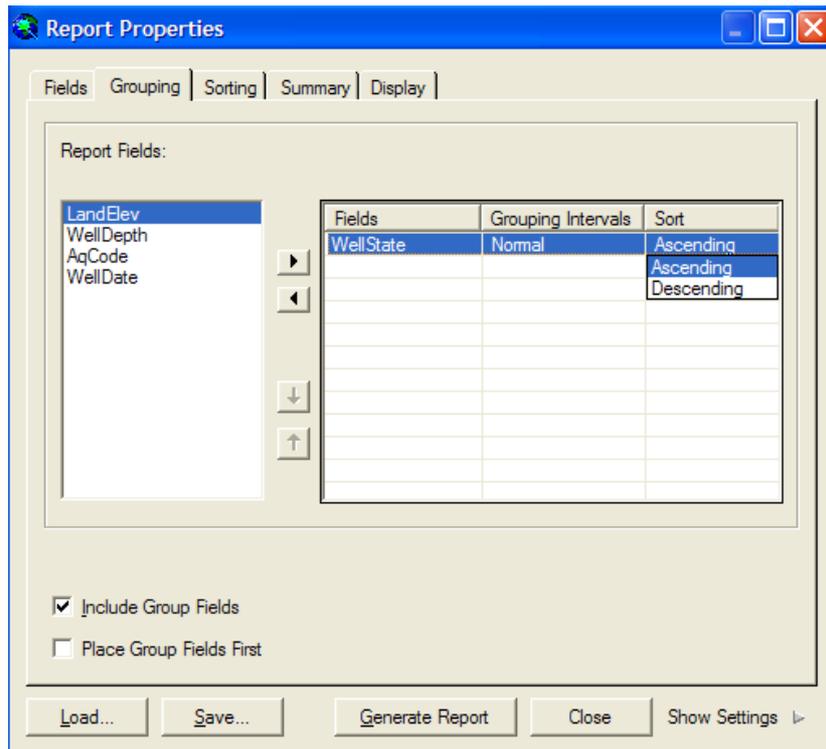
When the *Report Properties* window opens, only the *Fields* tab is available. Fields used for the report must be selected in the left column and transferred in the right column. They could be reordered using arrows on the right side.



3.3.1.2 *Grouping tab*

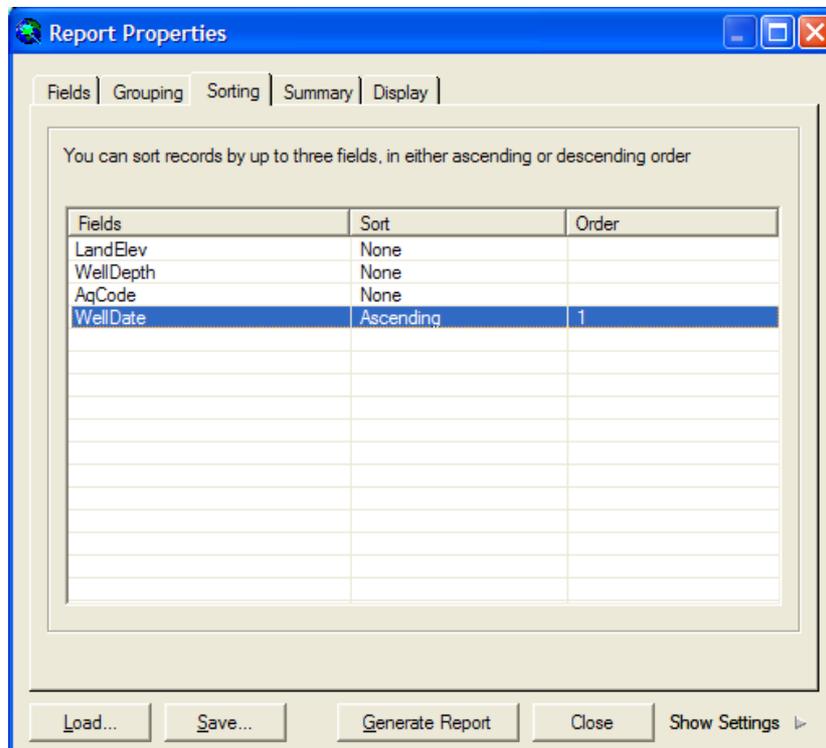
The *Grouping* tab is used to group reporting data using values in one or many fields. For example, data could be grouped by *WellState*.

Values used for grouping could be sorted ascending or descending way. They are usually included in the report but they could be useful only for grouping and could be hidden.



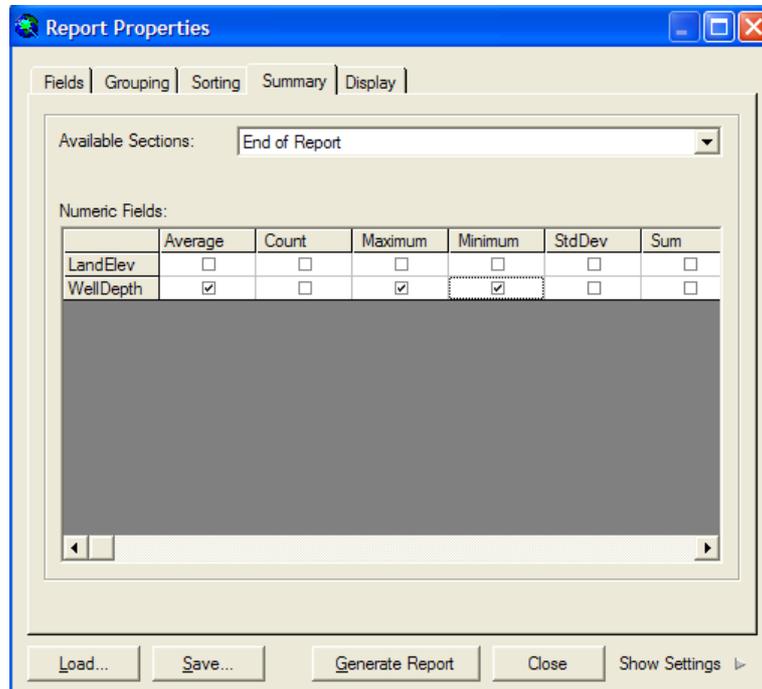
3.3.1.3 Sorting tab

The *Sorting* tab is used to sort reporting data using values in one or many fields. For example, data could be sorted by *WellDate*.



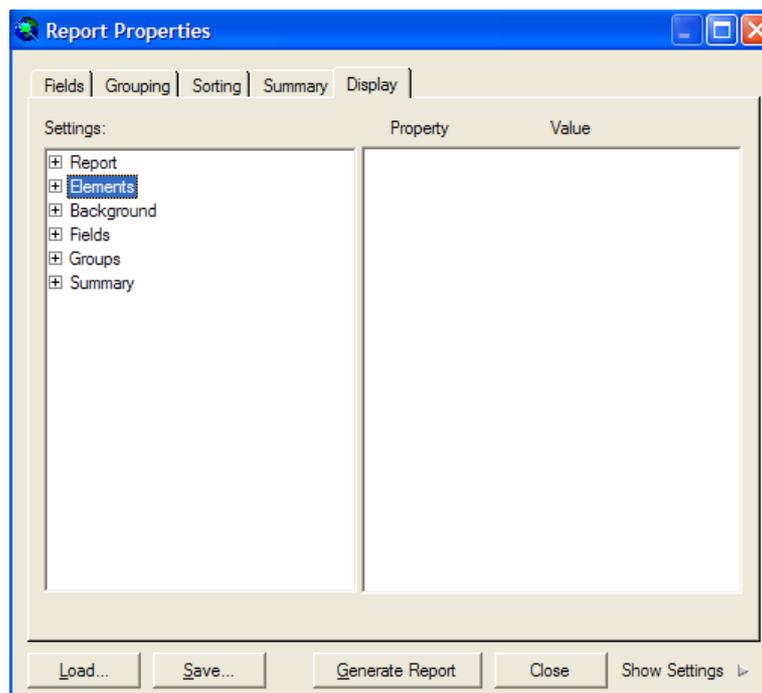
3.3.1.4 Summary tab

The *Summary* tab allows statistics (average, count, minimum, maximum, standard deviation and sum) on numeric fields. Results of summary are located at the end of the report.



3.3.1.5 Display tab

The *Display* tab allows the organization of the report presentation such as the title, column names, logo, font, etc. Six types of settings are available: *Report*, *Elements*, *Background*, *Fields*, *Groups* and *Summary*.



Report

Report settings concern the general organization of bottom and top of the report, bottom and top of pages, bottom and top of groups and records. Settings could be on background or shade color, visibility, borders, etc.

Settings:	Property	Value
[-] Report	Autosize	True
[-] Top of Report	Back Color	<input type="checkbox"/>
[-] Top of Page	Border	
[-] Top of Group WellState	Height	1
[+] Records	Keep Together	True
[-] Bottom of Group WellState	Shade Records	Every Other
[-] Bottom of Page	Shade Color	<input type="checkbox"/>
[-] Bottom of Report	Visible	True

Elements

Elements settings concern the definition of report elements properties like title, subtitle, logo, footnote, page numbering and date.

Settings:	Property	Value
[+] Report	Autosize	True
[+] Elements	Back Color	<input type="checkbox"/>
[-] Title	Border	None
[-] Subtitle	Font	Bradley Hand ITC
[-] Image	Height	0.3
[-] Field Names	Horizontal Alignment	Center
[-] Date	Left	0
[-] Page Numbering	Text	Well Statement
[-] Page Footnote	Top	1.041
[-] Report Footnote	Vertical Alignment	Bottom
	Width	6.479

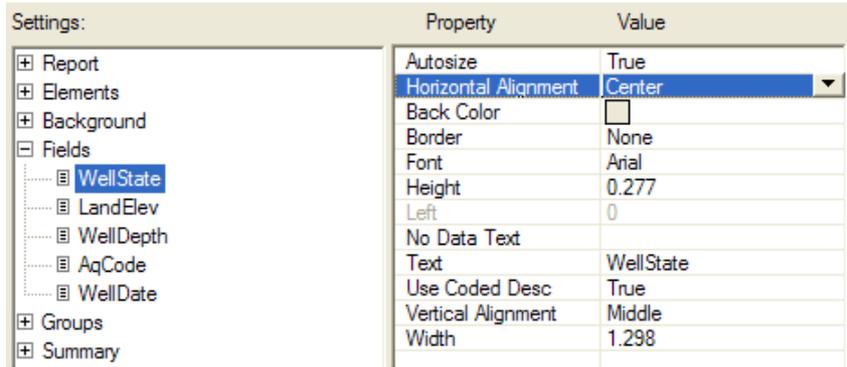
Background

Background settings concern the properties definition of a background text or background image.

Settings:	Property	Value
[+] Report	Left	0.711
[+] Elements	Picture	C:\Documents and Settin...
[+] Background	Top	0.711
[-] Text		
[-] Image		

Field

Fields settings concern display properties of each field selected in the Fields tag. Properties could be field name, font, width, etc.

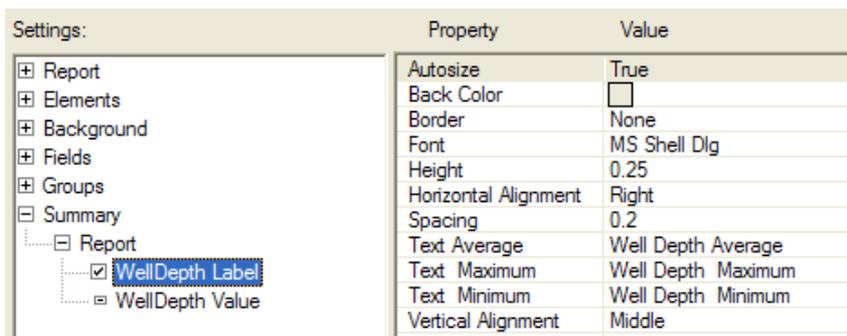


Group

Group settings concern display properties of each group created in the *Grouping* tag. Properties could be field width, background color, horizontal alignment etc.

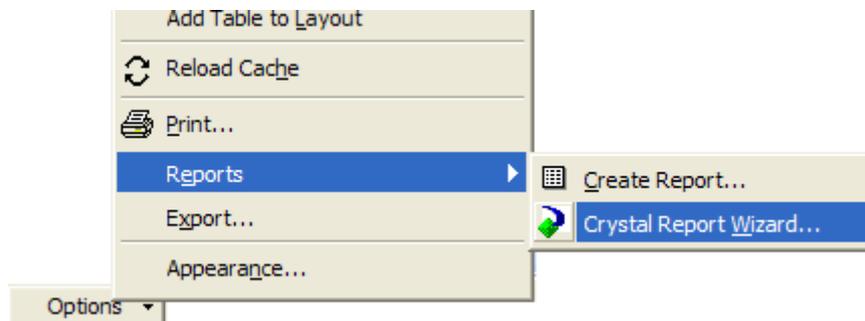
Summary

Summary settings concern properties of elements of the summary set in the *Summary* tag as titles, spacing, font, etc.

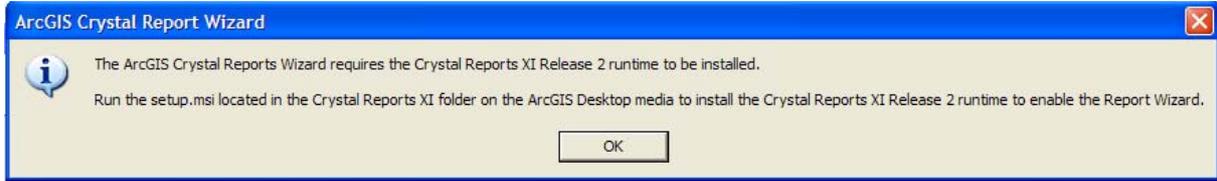


3.3.2 Reporting using Crystal Report wizard

Crystal Report is an external application that allows professional reporting. This application is operated using a wizard and it could be started using the *Crystal Report Wizard...* submenu.



The installation of this application is independent from *ArcGIS* but could be realized with the same installation CD. If *Crystal Report* is not installed, an error message will appear.



3.4 Working with graphs

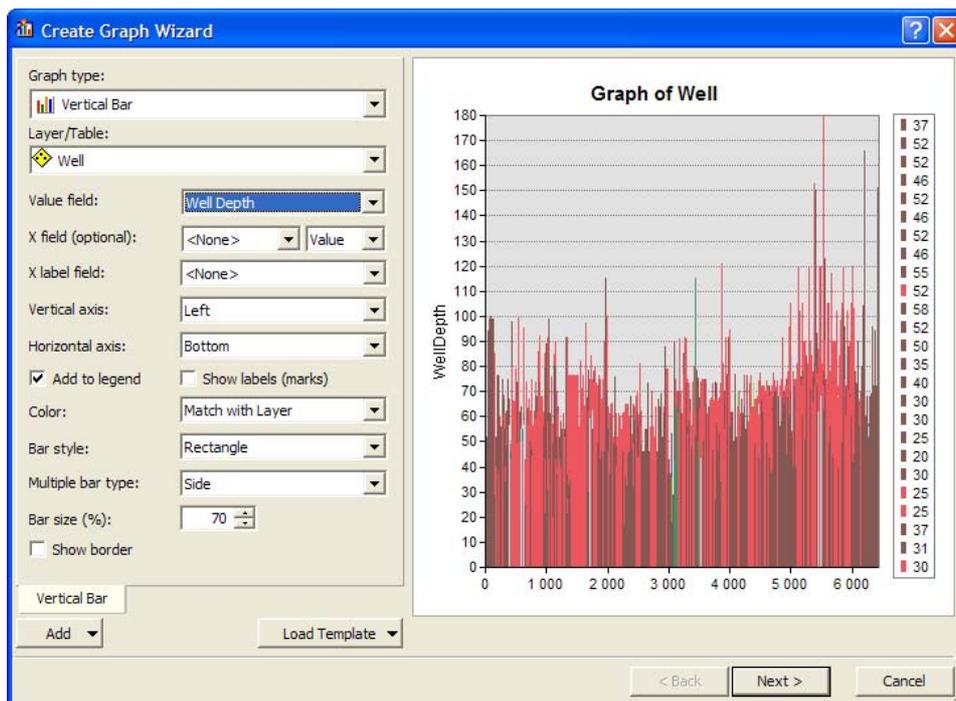
3.4.1 Creating a graph

A graph can be created using *Tools-Graphs-Create...* menu or *Create Graph...* submenu from the *Options* menu from the table interface.



The *Create Graph Wizard* will open. The first step corresponds to the *Series* tab of the *Graph Properties* window (All properties of the *Graph Properties* window will be detailed).

Some properties as *Layer/Table* and *Value field* could be set. A preview of the graph will appear on the right side of the wizard.

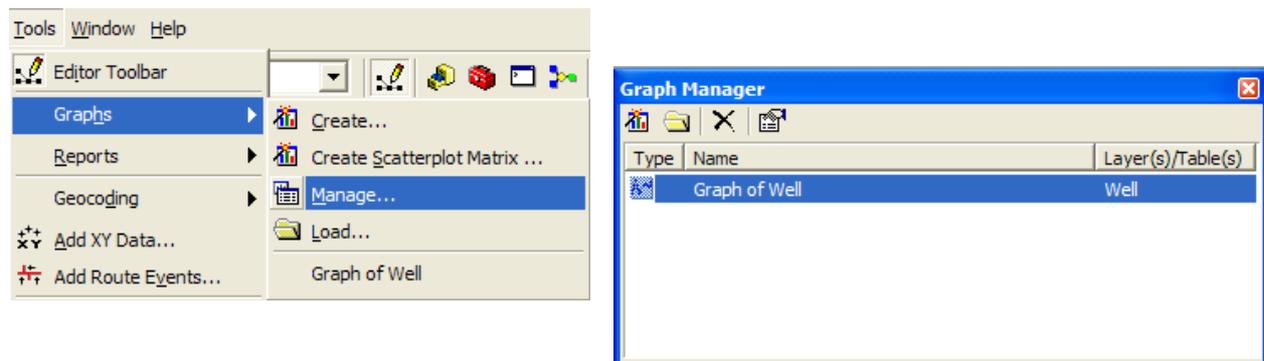


The *Next* button has to be clicked to go to the second step. It corresponds to the *Appearance* tab of the *Graph Properties* window. The *Finish* button has to be clicked to definitely create the graph. Properties can at any moment be modified using the *Graph Properties* window.

3.4.2 Managing graphs

Many graphs could be created. They will appear at the bottom of the *Tools-Graphs* menu. They could then be open directly if they are selected.

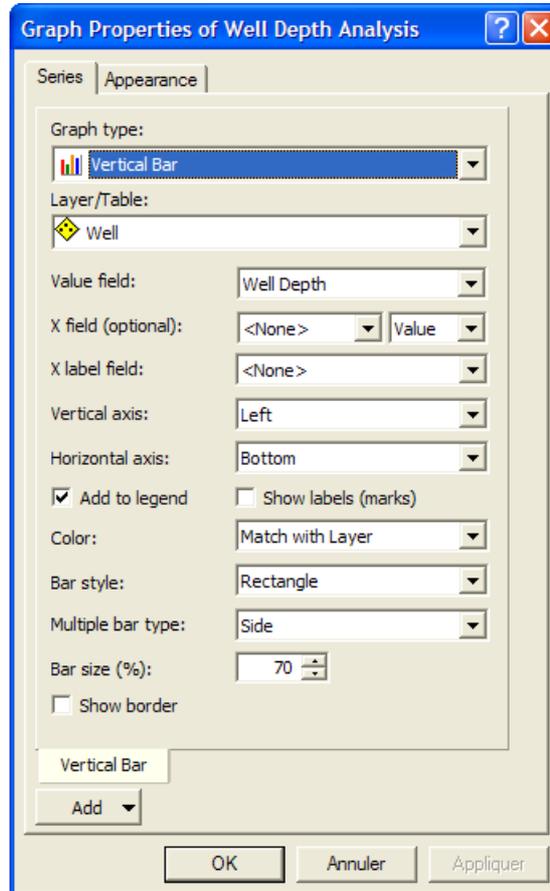
They could be managed using the *Tools-Graphs-Manage...* menu. *Graph manager* window will open. Each graph could be renamed by a *click* on the name, open by a *double-click*, deleted using the *Delete* button, and properties modified by accessing the *Graph Properties* window using the *Properties* button.



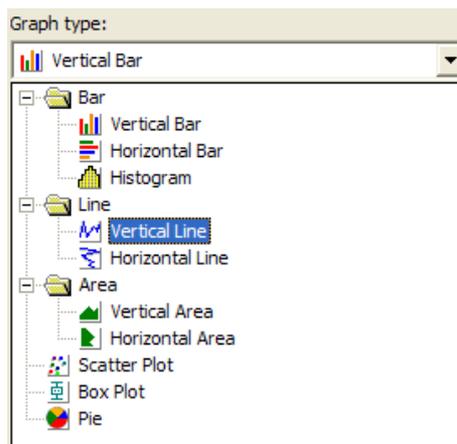
3.4.3 Editing graphs

Graph properties could be modified at any moment using the *Graph Properties* window. The easiest way to access this window is by a *double-click* on the graph window. The *Graph Properties* window has two tabs: *Series* and *Appearance*.

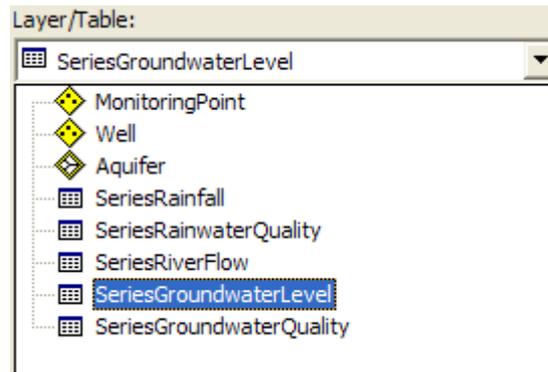
3.4.3.1 Series tab



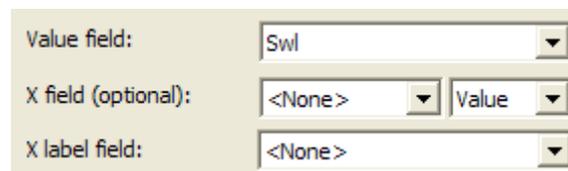
The first part is the *Graph type*. Many type of graph are available: bar, line, area, scatter plot, box plot and pie.



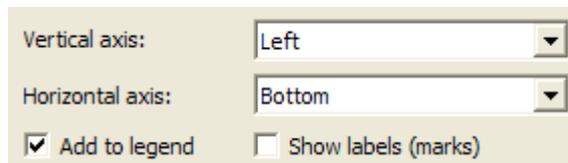
The second part is the *Layer/Table* used to create the graph. This properties has to be set absolutely, otherwise no data will appear on the graph.



The *Field* part allows the definition of the field containing values used to generate the graph. The *Value field* is necessary and will constitute values for the Y axis. X field is optional and will be used for example to present two interdependent variables meaning one has an influence on the other.



The *Axis* part allows the definition of the position of the vertical and horizontal axis. Values could be added to the legend and labelled directly on the graph.

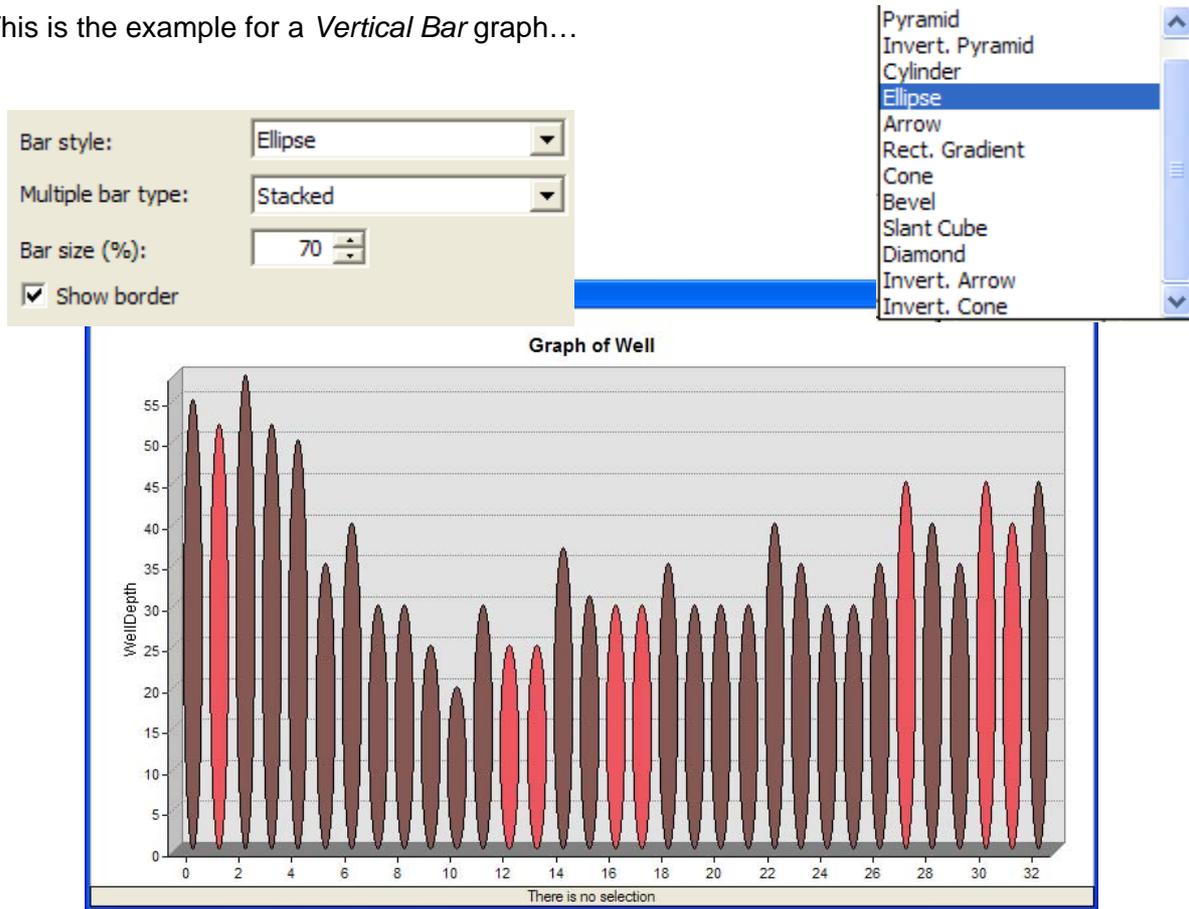


The *Color* part allows the definition of the way colors will be applied on the graph. The *Match with Layer* option means that colors will be the same than colors of the layer legend in the *Table of Contents*. Other options allow the definition of other colors.

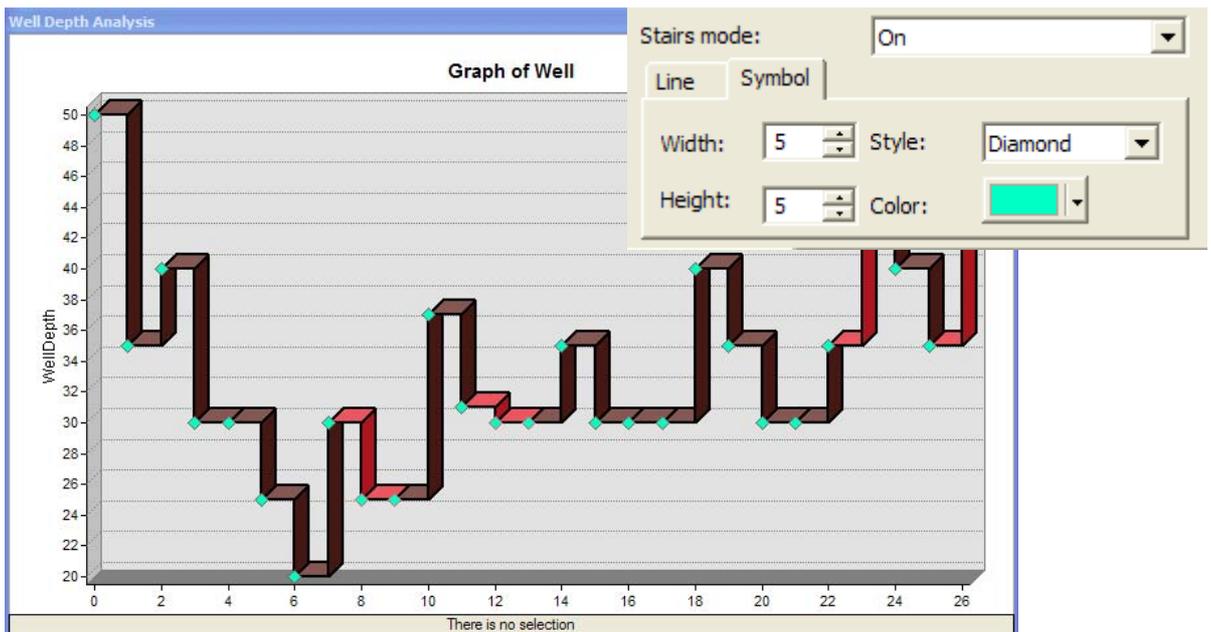


The *Graph presentation* part, depending of the graph style defined in the *Graph type* part, allows the modification of the presentation of elements in the graph.

This is the example for a *Vertical Bar* graph...



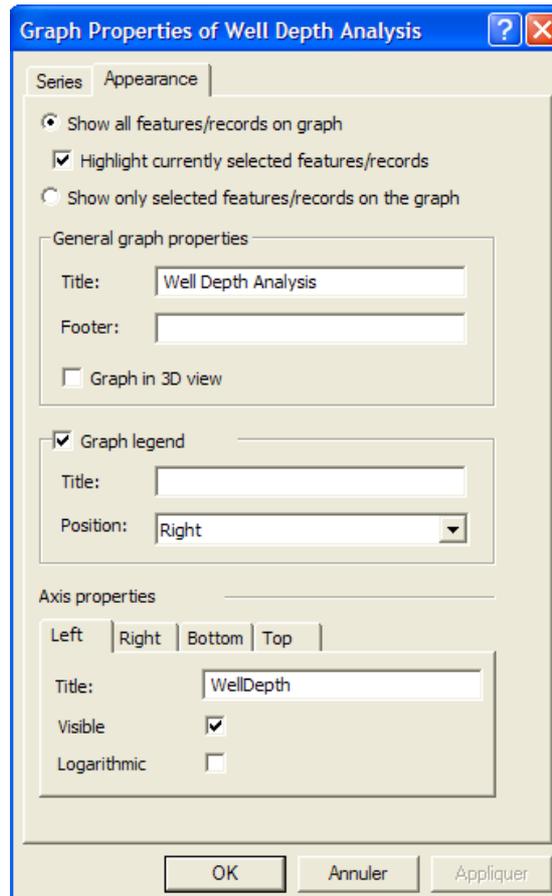
...and for a *Vertical Line* graph.



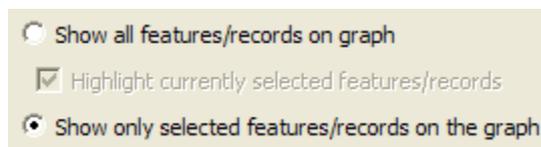
To be able to compare data, additional vertical bars could be added to the graph. An example could be to compare different water quality.



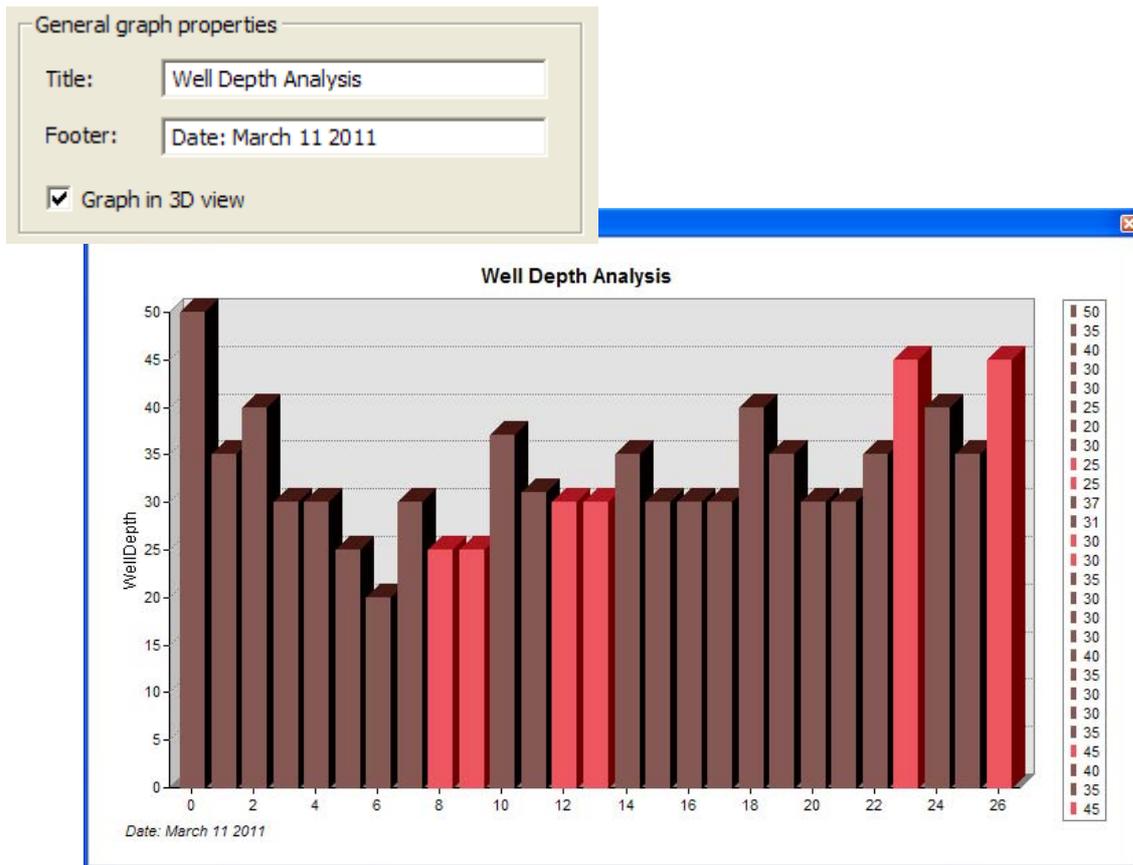
3.4.3.2 Appearance tab



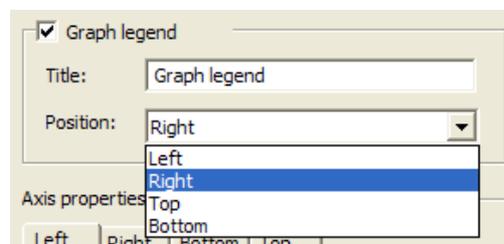
The first part of the tab allows setting what will be used in the graph: all records or a subset.



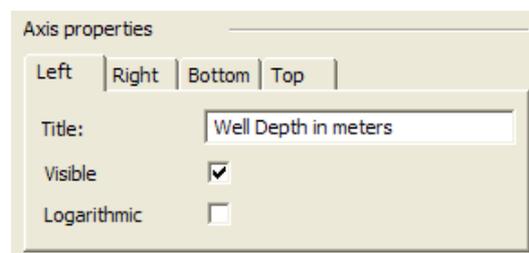
The part *General graph properties* part allows setting a title and a footer. The title will appear at the top-center of the graph. The title also becomes the name of the graph. Footer is a note that will appear in the bottom-left corner of the graph. It is also possible to present the graph in 3-D.



The part *Graph Legend* allows setting a title for the legend and to modify the legend position.



The part *Axis properties* allows to set title for each axis. Of course, they have to exist and be visible otherwise the title set will not appear.



3.5 Creating maps

Mapping is necessary to present information from a database, results produced by an analysis, etc.

Mapping is an art but also a science. Many cartographic rules exist to give standardization to mapping product. For example, it is always important to present a scale and a legend because those elements are necessary to read and understand the map.

Before to begin a map, it is important to have a work plan and answer to some questions. Who will use it? What kind of information this person will need? Why this person needs this map? What this map is this for?

A map must be simple and clear as possible but with the maximum of pertinent information. A map with too much information could be unreadable and unusable. It is always important to remember who will use the map. It will help to select pertinent information.

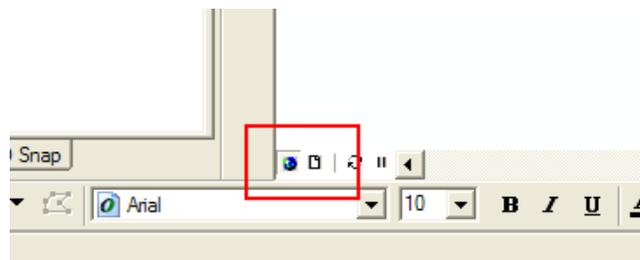
If a map is produced for a report, the format has to be practical to ensure the map will be integrated easily. If a map will be used on field and present a lot of information, maybe a large format will be more efficient.

If a map is produce to present a final product in a report, the quality level will be higher. But if a map is produced as a work tool on the field, the quality is not maybe necessary.

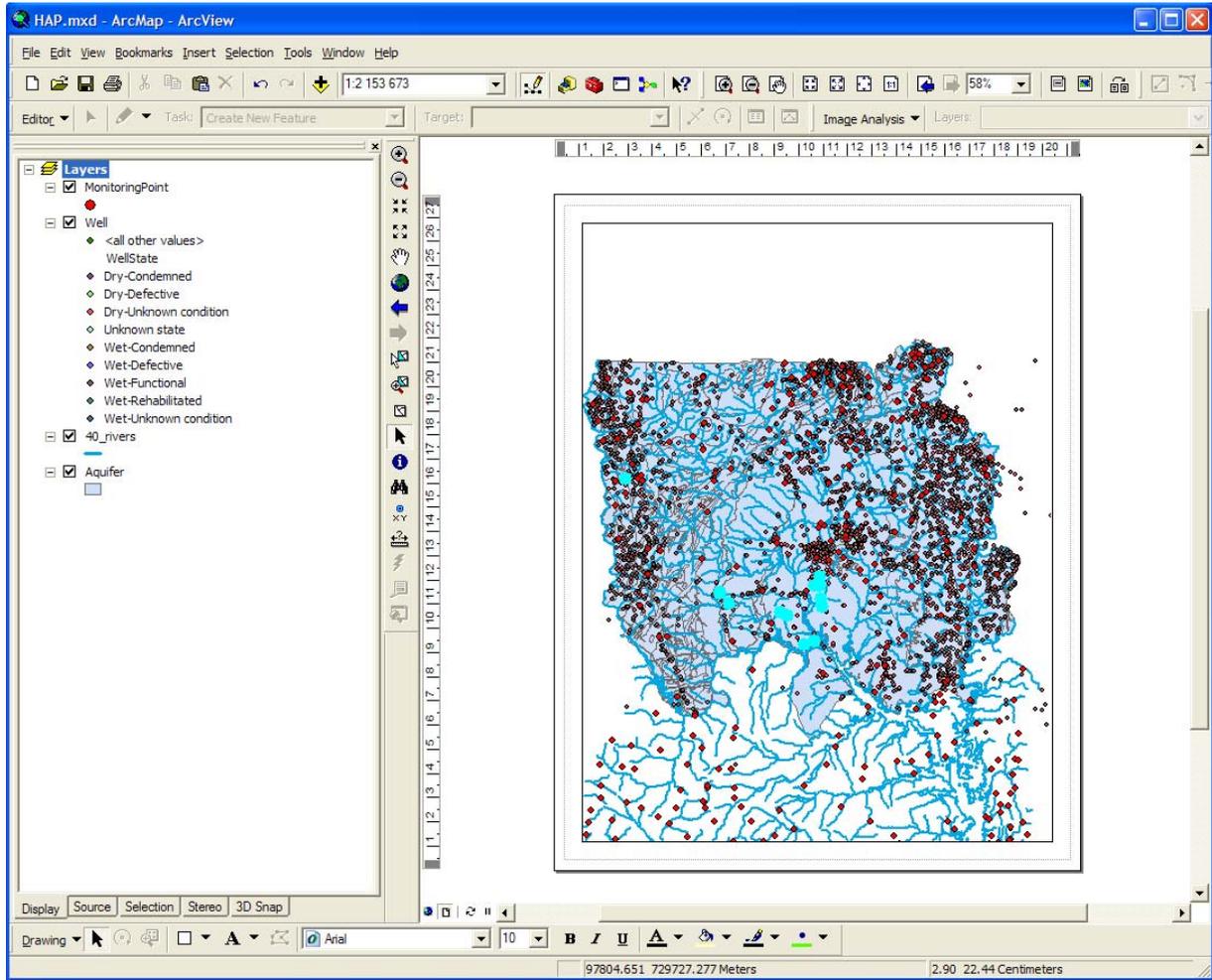
A minimum of reflection is then necessary before to begin a map production

3.5.1 Mapping environment

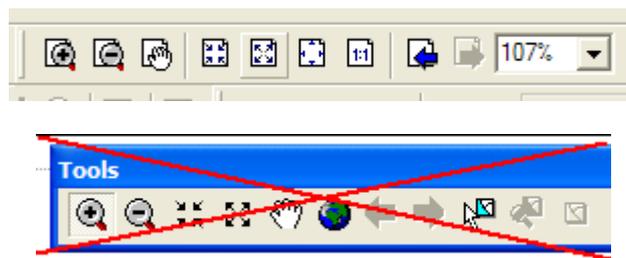
ArcMap presents two types of environment or view: Data view and Layout view. It is possible to switch from a view to another using the two buttons at the bottom-left of the view area window.



The layout view is used for mapping. When it is activated, a rectangle, representing a sheet of paper, appears. The only element present will be data frames in the table of contents.

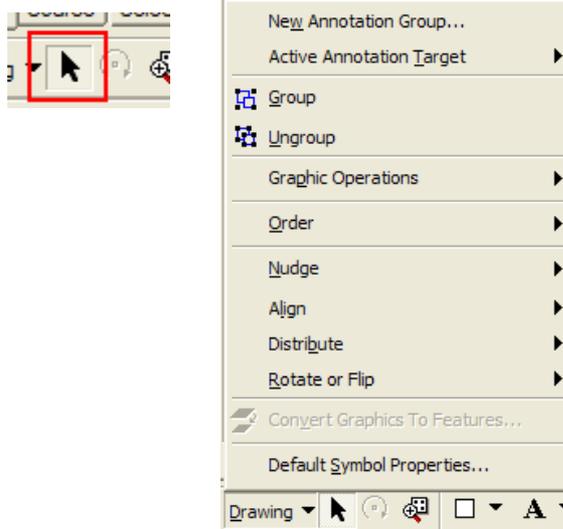


To navigate in the layout, tools from the Layout toolbar must be used. Otherwise, navigation operation will not be applied on the layout but on the active data frame. If the *Layout* toolbar is not visible, it could be open using the *View-Toolbars-Draw* menu.

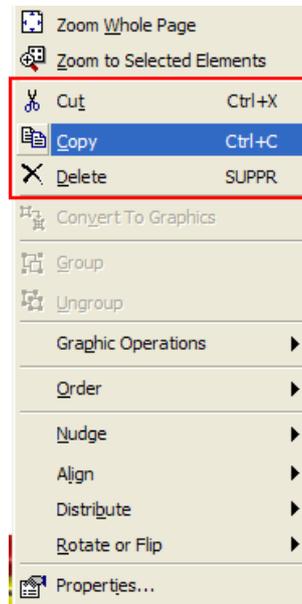


Each element put on the map can be reorganized using one of the options in the *Draw* menu from the *Draw* toolbar (bottom-left) or by a *right-click* on the selected element.

Elements must be selected first using the button and after they could be grouped together, ungroup, align, distribute, rotate, etc. If the *Draw* toolbar is not visible, it could be open using the *View-Toolbars-Draw* menu.



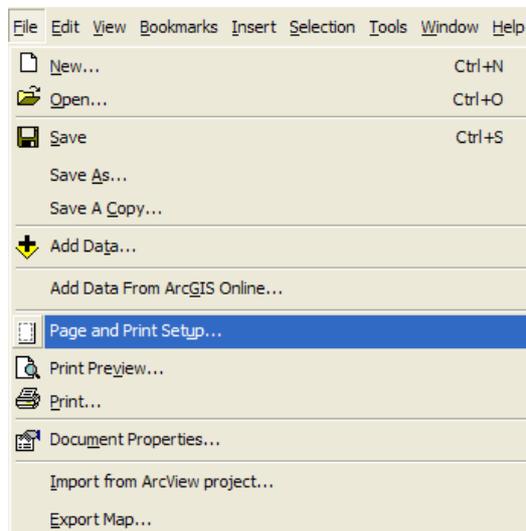
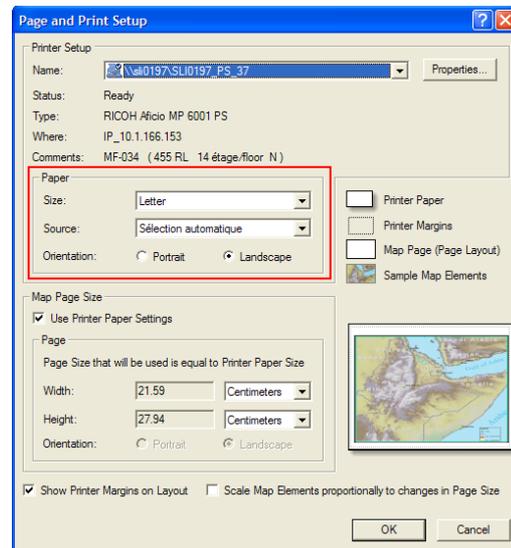
Elements could also be *copy*, *cut*, *paste* and *delete* using a *right-click* on the selected element.



3.5.2 Mapping settings

3.5.2.1 Page format

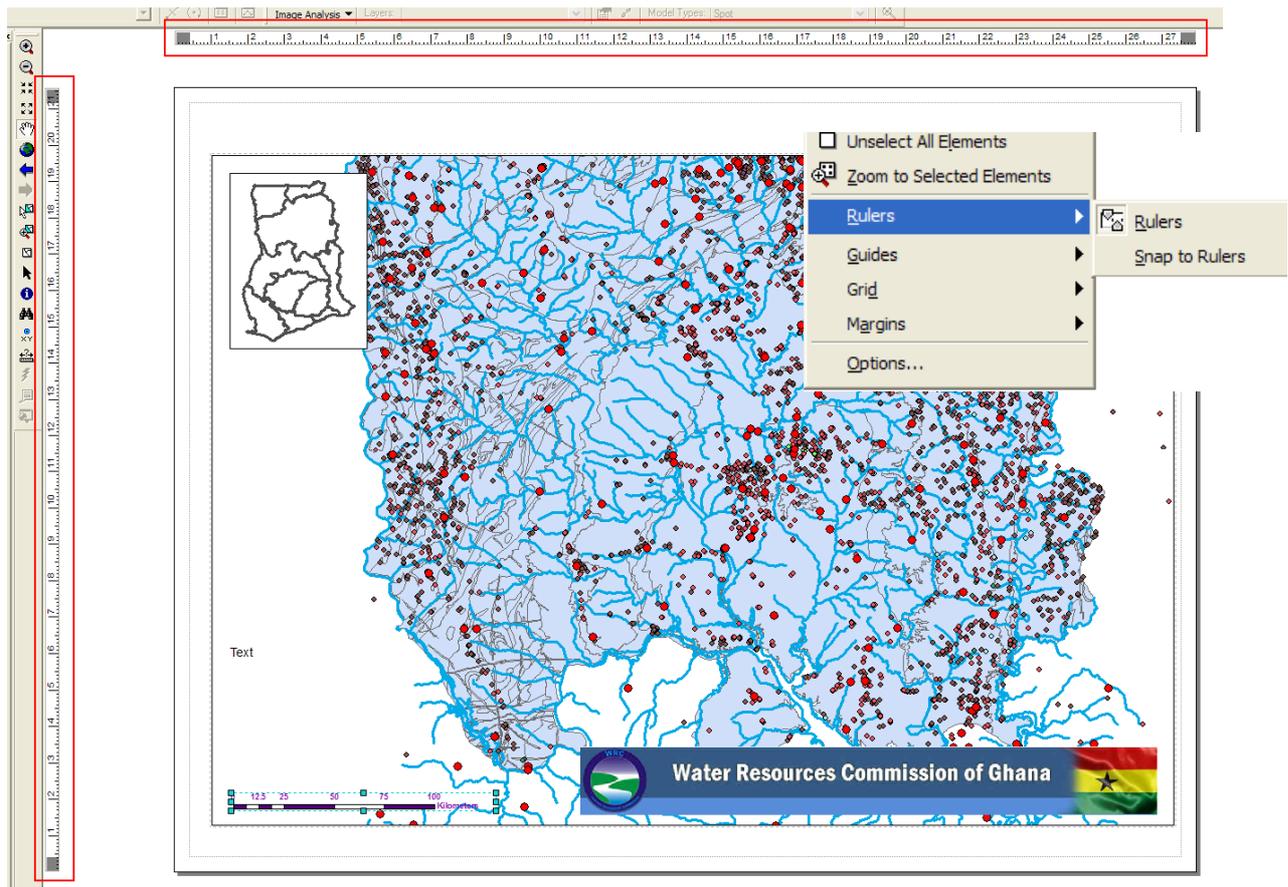
Page format must be set at the beginning. It could be done using the *File-Page and Print Setup...* menu. The section *Paper* allows selecting the size and the orientation of the layout.



3.5.2.2 Using and setting guides

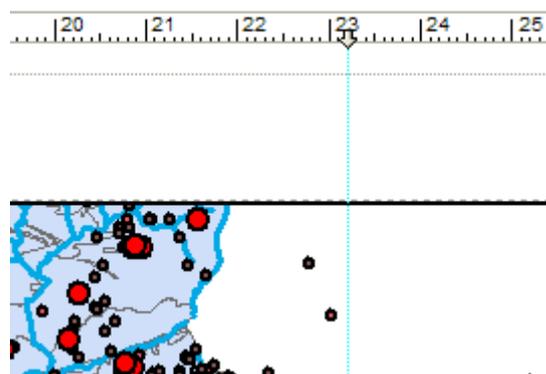
A map is a set of different elements. To ensure that each element on the map is aligned, guides can be set on rulers.

Rulers are on each side of the layout. They could be hidden or not by a *right-click* on the layout and using the *Rulers-Rulers* menu or by a *right-click* on the ruler and using *Hide Rulers* menu.

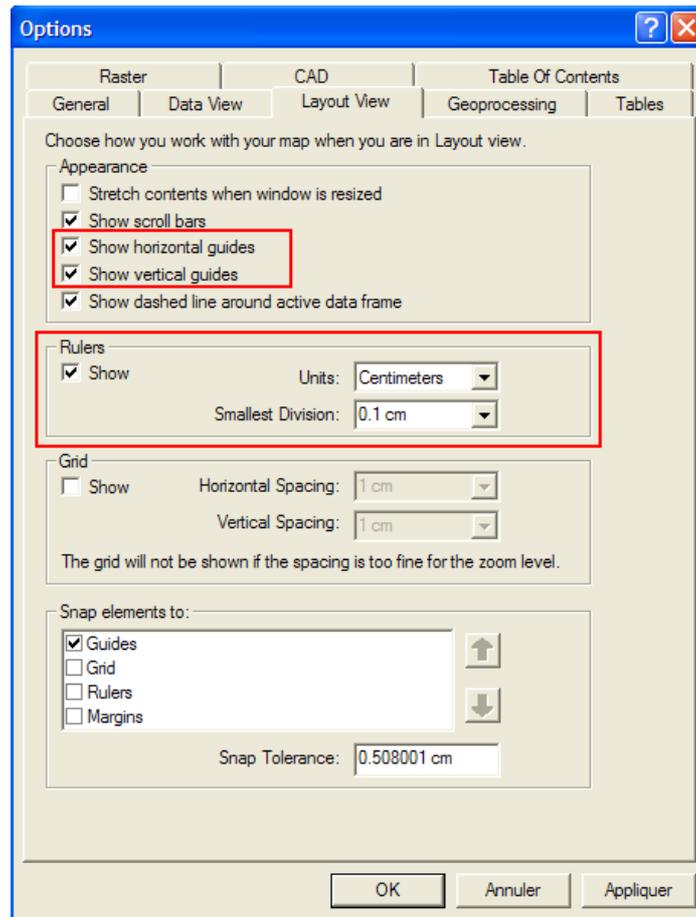


A guide is set only by a *click* on a ruler. It can also be set by a *right-click* on the ruler and using *Set Guide* menu.

A small arrow will appear on the ruler and a cyan line will cross the layout to indicate the position of the guide. A guide could be moved by a *click-and-drag* on the small arrow. It could also be removed by a *right-click* on the ruler and using the *Clear Guide* menu (or *Clear All Guides* to remove all guides).



It is possible to set rulers and guides properties in the *Options* window (*right-click* on the ruler or on the layout and use *Options* menu). Guides could be hidden and to get more accuracy in alignment, units could be modified for rulers.

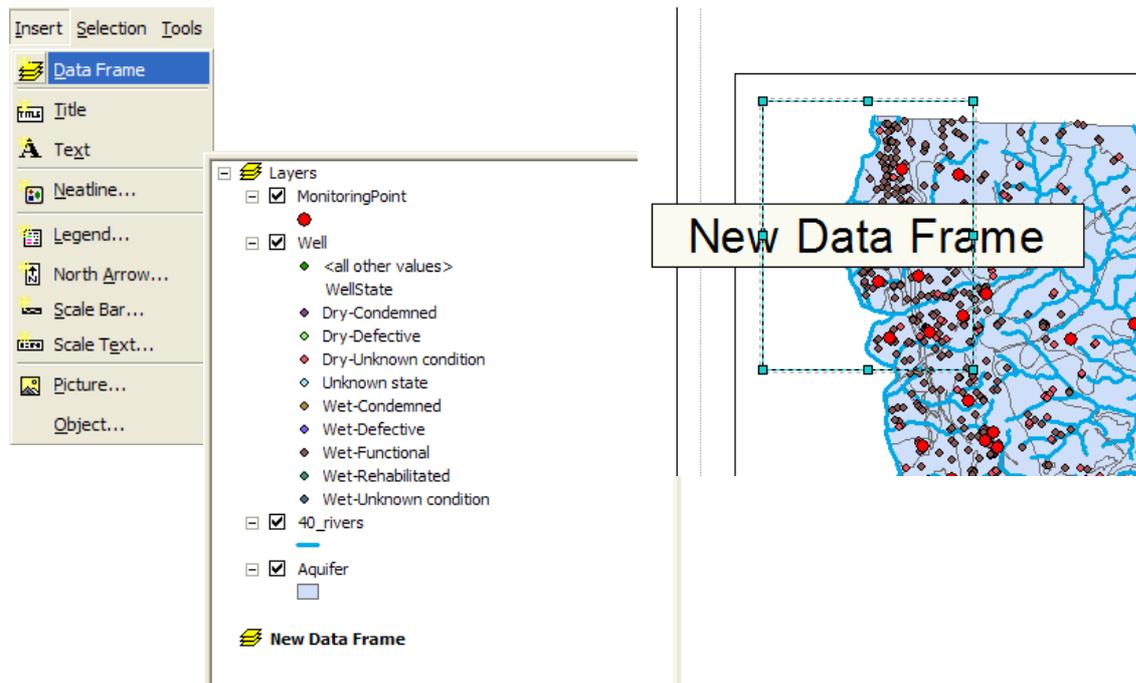


3.5.3 Mapping elements

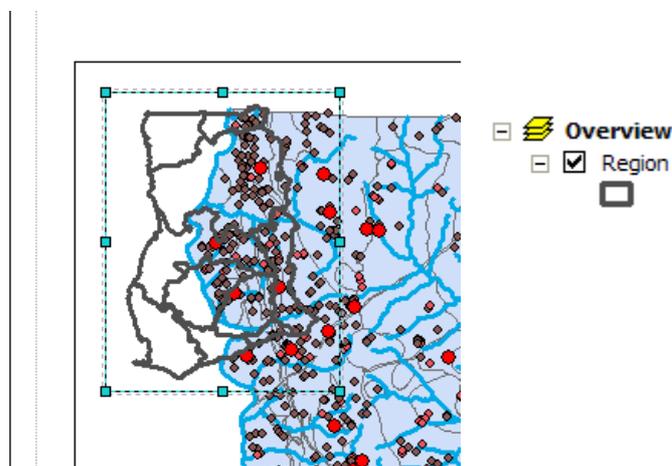
A layout or a map can contain many elements but they could be only of seven types: *Data Frame*, *Legend*, *North Arrow*, *Sc*

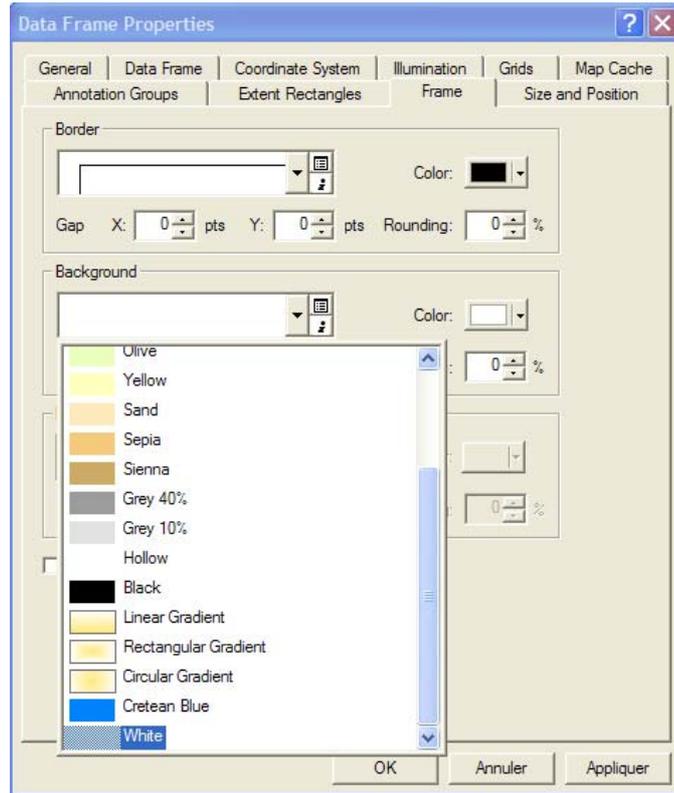
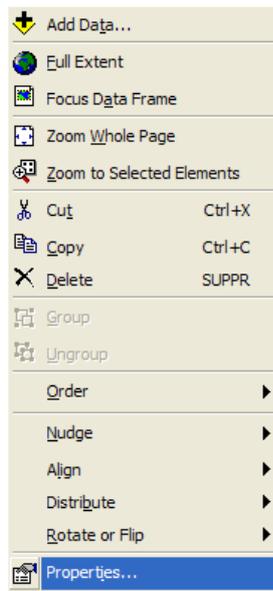
3.5.3.1 Data Frame

A data frame could be added using the *Insert-Data Frame...* menu. An empty data frame will appear in the *Table of contents* and in the layout with a banner "New Data Frame". By default, the new data frame will become the active data frame.



Each new layer added to the data frame will appear automatically in the layout. Interactions in the data frame are dynamics. For example, if the symbology of layers changes, modifications will reflect in the layout. The background and border of a data frame could be modified in the *Frame* tab of the *Data Frame Properties* window. This window could be accessed using a *right-click* on the data frame and the *Properties...* menu.

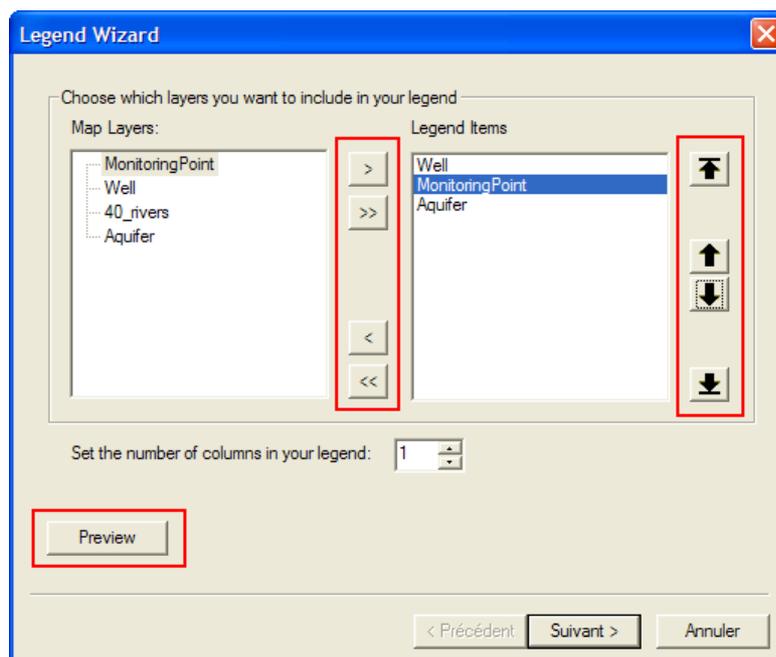
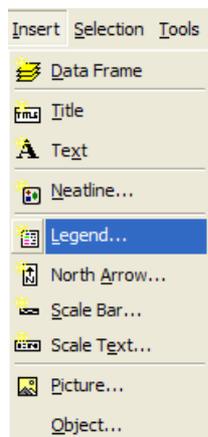




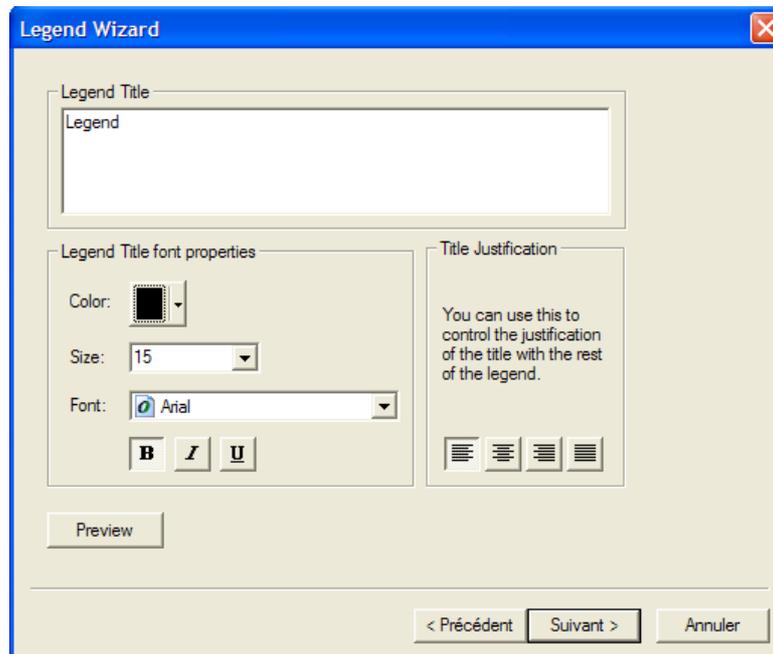
3.5.3.2 Legend

A legend could be added using the *Insert-Legend...* menu. The *Legend Wizard* window will appear. Layers present in the *Table of Contents* are visible in the left column. Each layer moved to the right column using “arrows” buttons in the center will appear in the legend. Layers selected for legend could be reorganized using “arrows” buttons on the right side and it is possible to organize the legend in one or many columns.

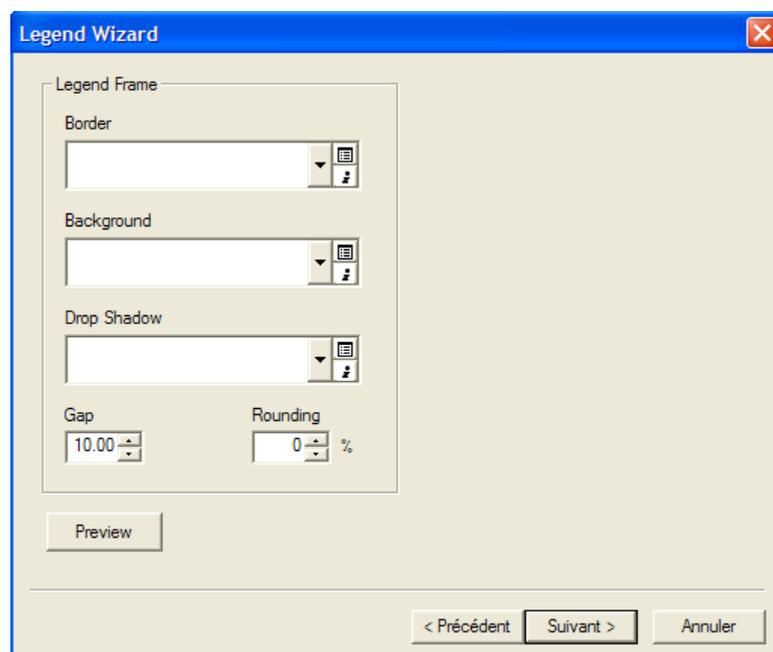
At any moment, the *Preview* button can be clicked to visualize the result.



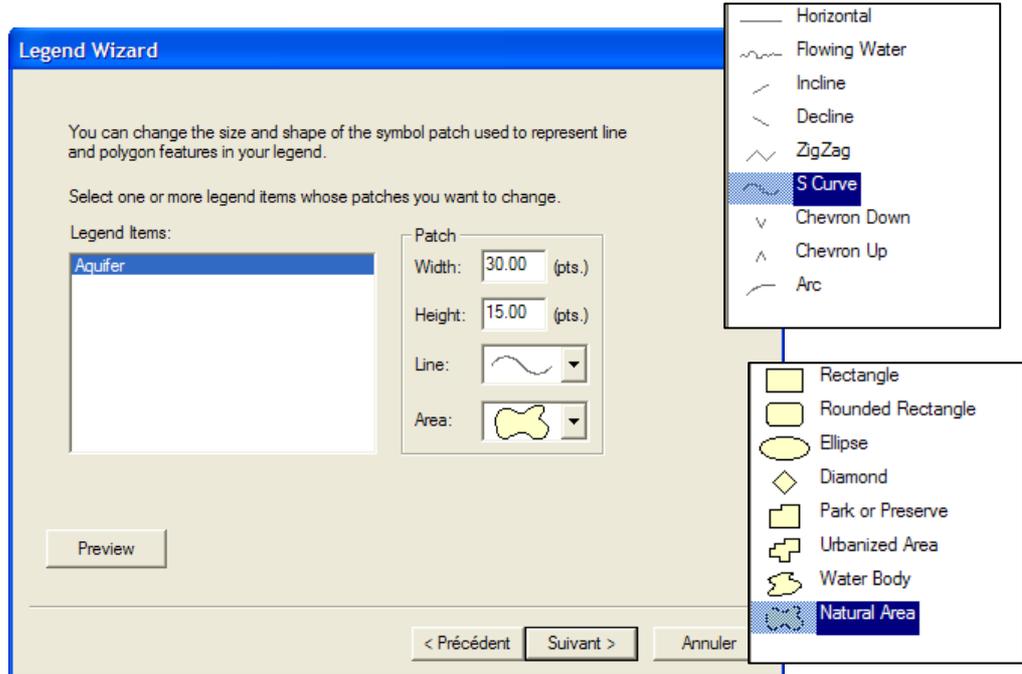
The second step of the *Legend Wizard* window allows setting properties of the legend title as color, size, font, etc.



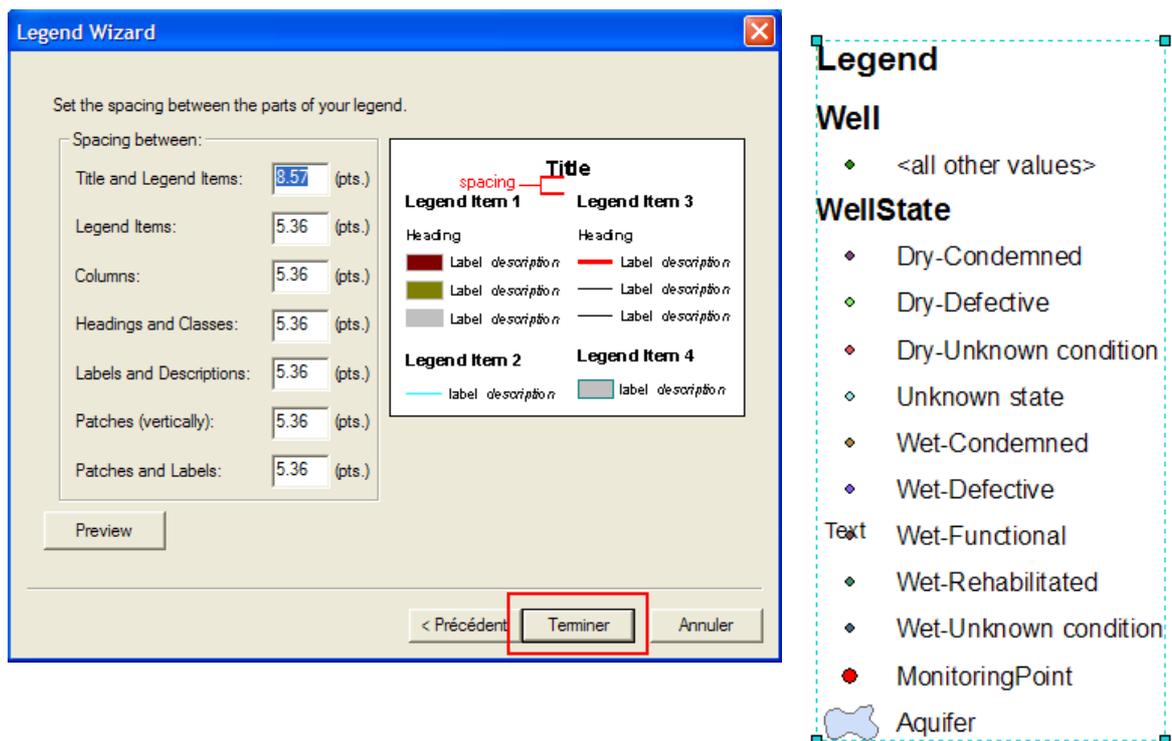
The third step of the *Legend Wizard* window allows setting legend frame properties as border, background and drop shadow.



The fourth step of the *Legend Wizard* window allows setting legend symbols properties as width and height. Lists of different line and polygon design are also available.



The last step of the *Legend Wizard* window allows setting the spacing of legend elements. To finish the legend creation, the button *Finish* has to be clicked.

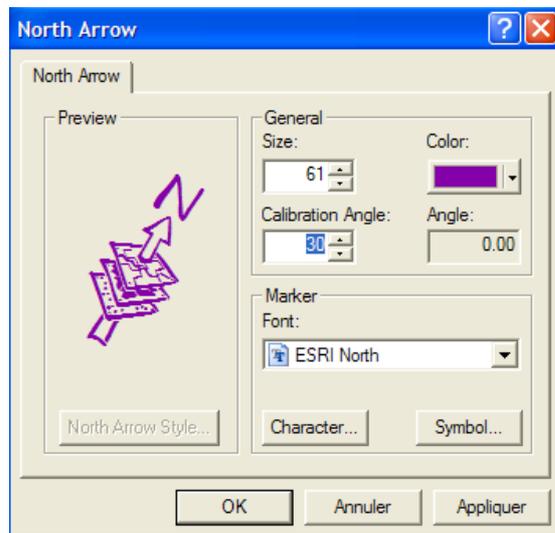
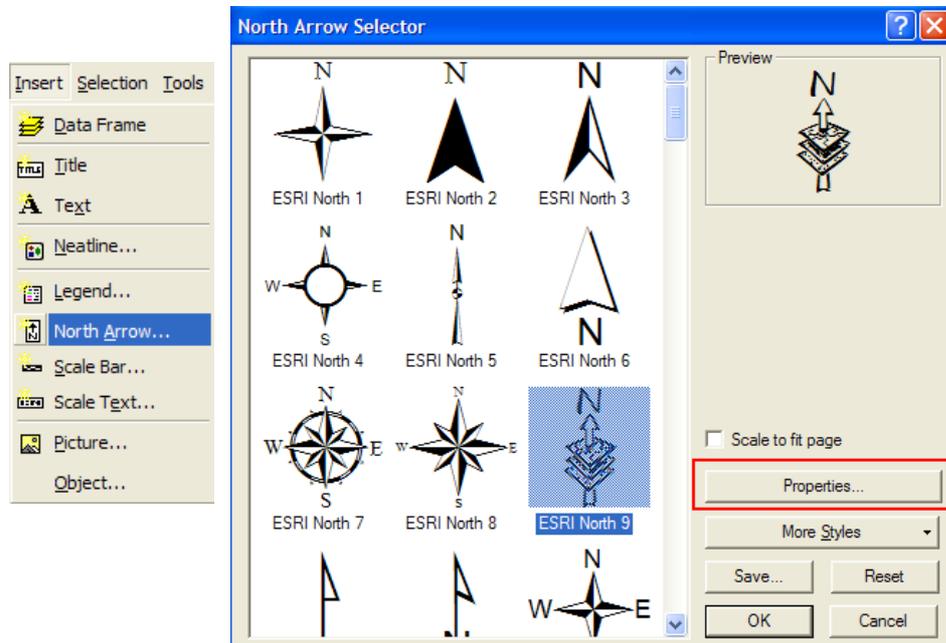


Legend created is dynamic with layers in the *Table of Contents*. If a layer is renamed or the classification is changed, modifications will be reflected in the legend.

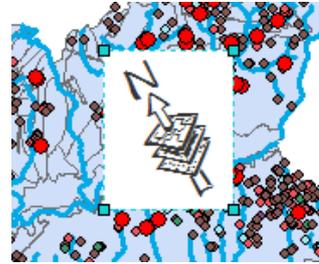
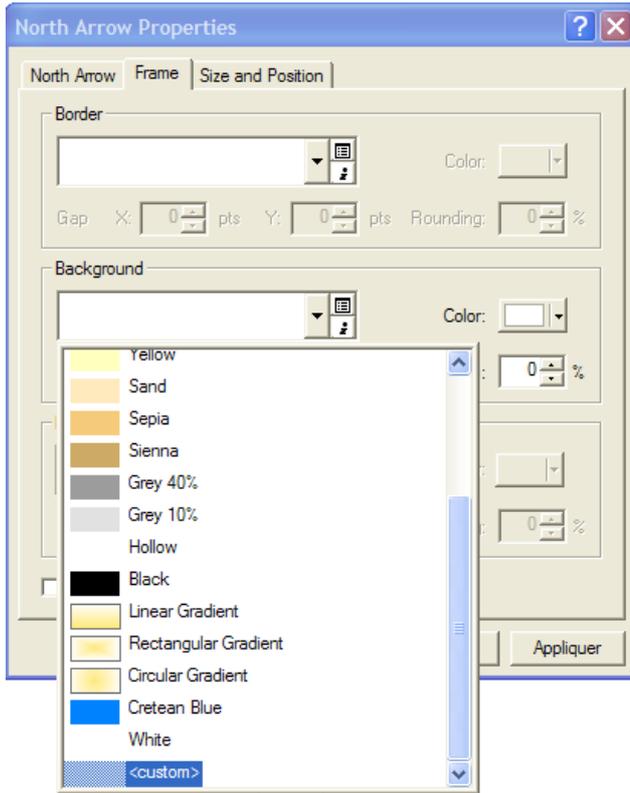
At any moment it is possible to access the *Legend Properties* window using a *double-click* on the legend to modify its properties.

3.5.3.3 North arrow

A north arrow could be added using the *Insert-North Arrow...* menu. The *North Arrow Selector* window will appear.



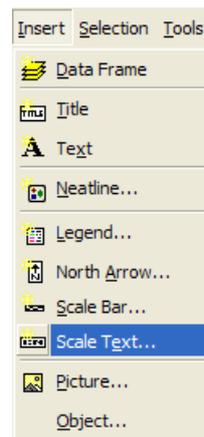
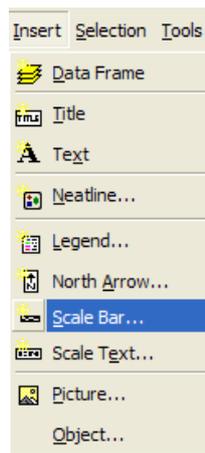
At any moment it is possible to access the *North Arrow Properties* window using a *double-click* on the north arrow to modify its properties. It could be the position, the background color, the orientation or the color.



Note: A north arrow is not necessary if the map is not oriented. The north orientation will be assumed as straight.

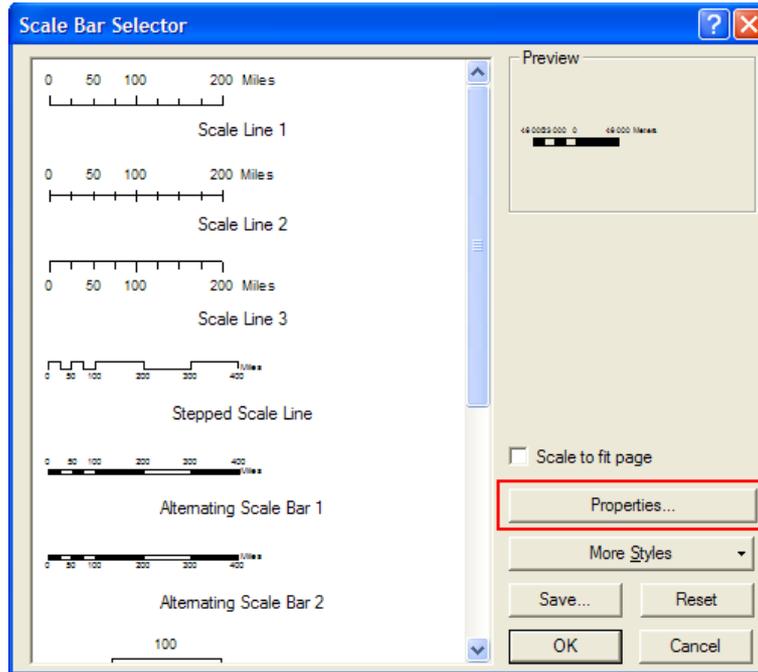
3.5.3.4 Scale

A scale could be added using the *Insert-Scale Bar...* and *Insert-Scale Text...* menus.



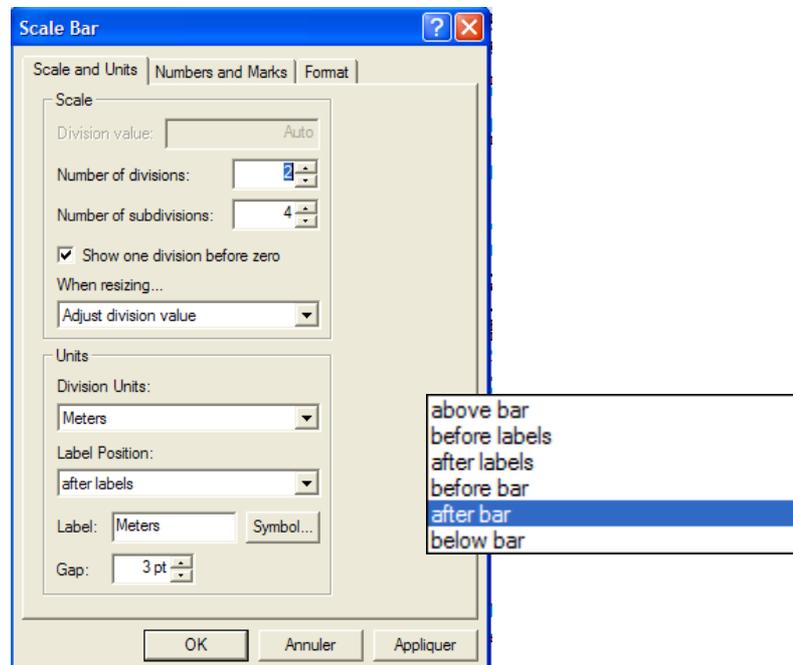
Scale Bar

If the *Insert-Scale Bar...* menu is selected, the *Scale Bar Selector* window will appear. A style of scale has to be chosen and its properties could be modified by a *click* on the *Properties* button to access the *Scale Bar* window.

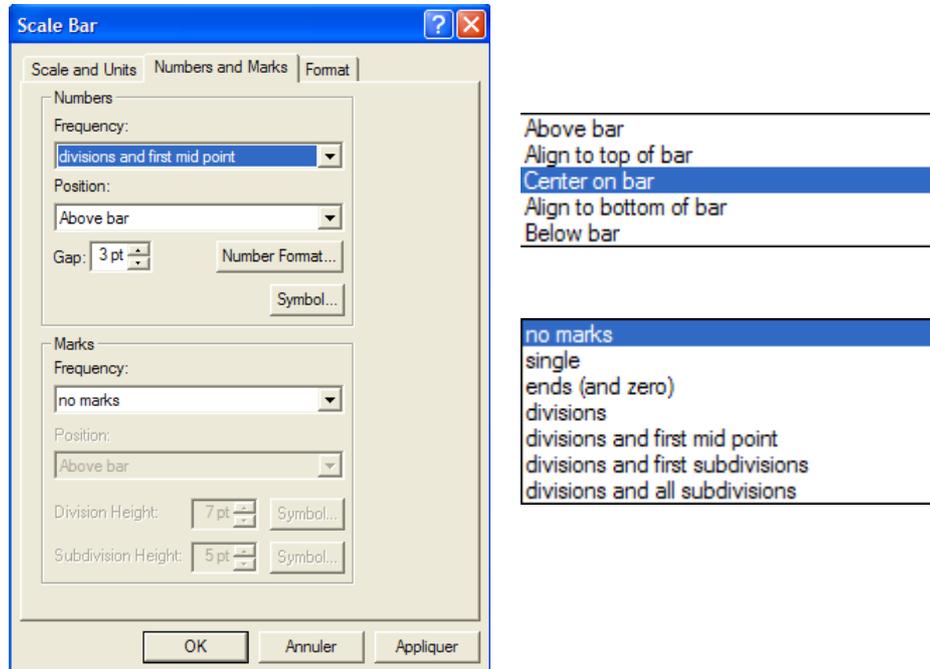


The *Scale Bar* window has three tabs: *Scale and Units*, *Numbers and Marks*, and *Format*.

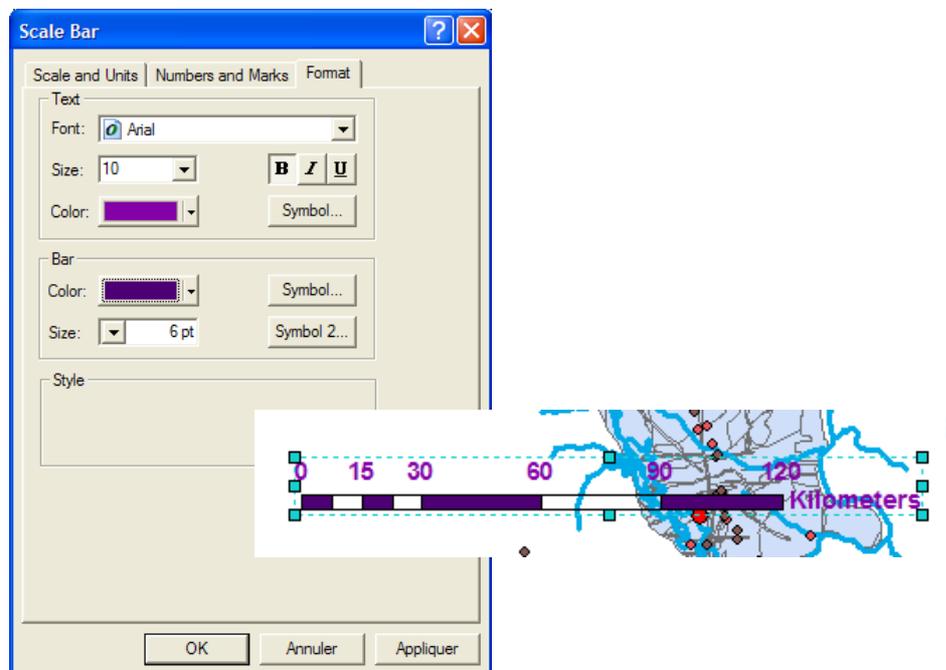
The *Scale and units* part allows managing divisions of the scale bar: Number of divisions and subdivisions, division before the zero value and how divisions will be reorganized when resizing. This part also allows defining units and the label position of those units.



The *Numbers and Marks* tab allows setting the position and the frequency of numbers and marks that appear on the scale bar. The position of numbers and marks could be *Above*, *Center*, *Below*, *Align to top* and *Align to bottom*. Many frequencies are also available.



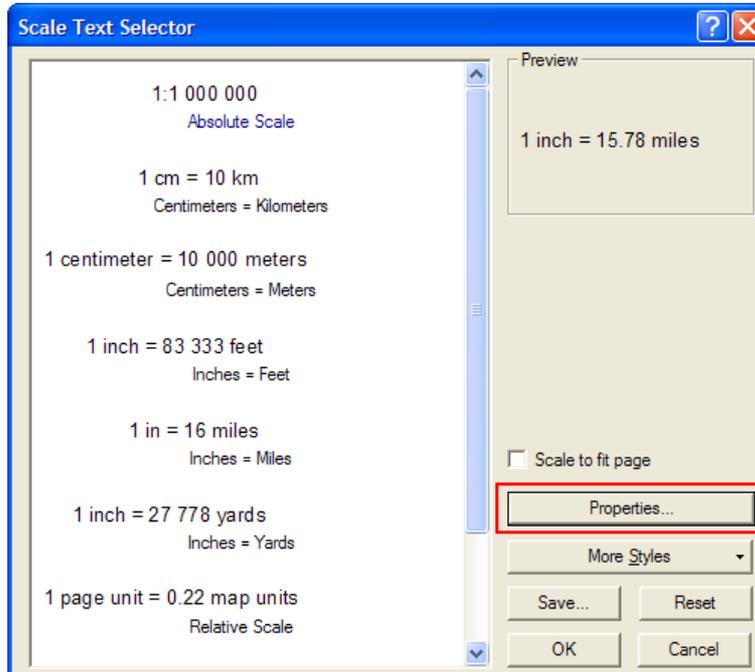
The *Format* tab allows defining text properties of the scale bar as color, size and font. It also allows the modification of the bar color and its size.



After the creation of the scale bar, the *Scale Bar Properties* window can be accessed at any moment by a *double-click* on the scale bar.

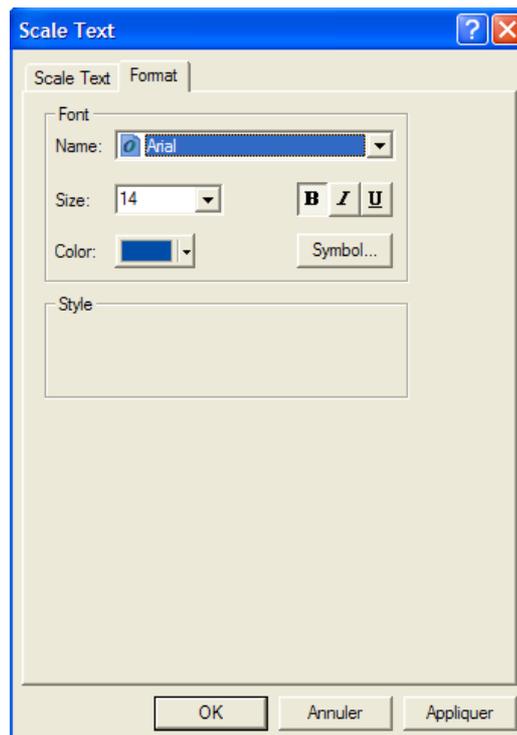
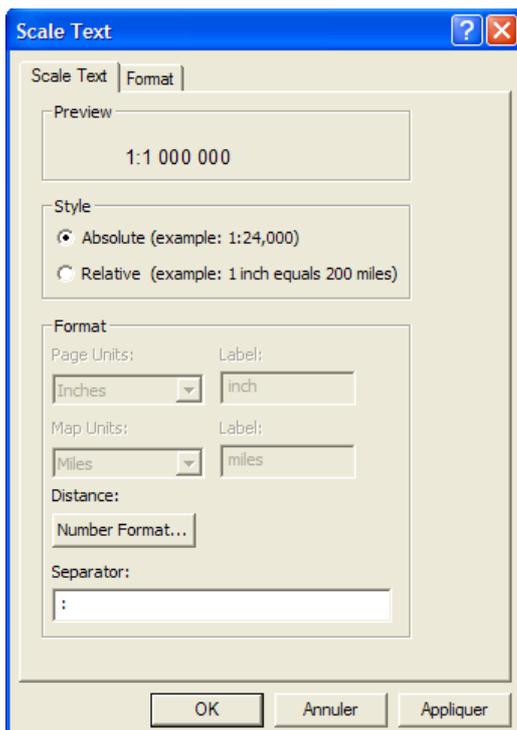
Scale Text

If the *Insert-Scale Text...* menu is selected, the *Scale Text Selector* window will appear. A style of scale has to be chosen and its properties could be modified by a *click* on the *Properties* button to access to the *Scale Bar* window.



The *Scale Text* window has two tabs: *Scale Text* and *Format*.

Scale Text tab allows setting the presentation of the scale text as the style, units and separator. The *Format* tab allows the modification the font and the color.

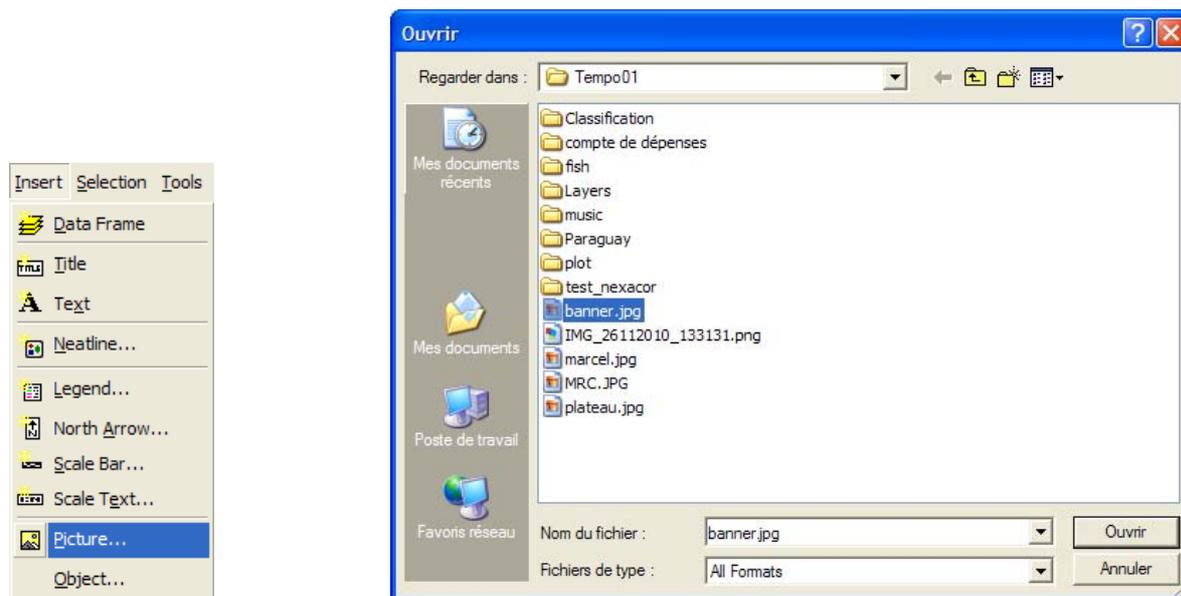


1:1 813 390

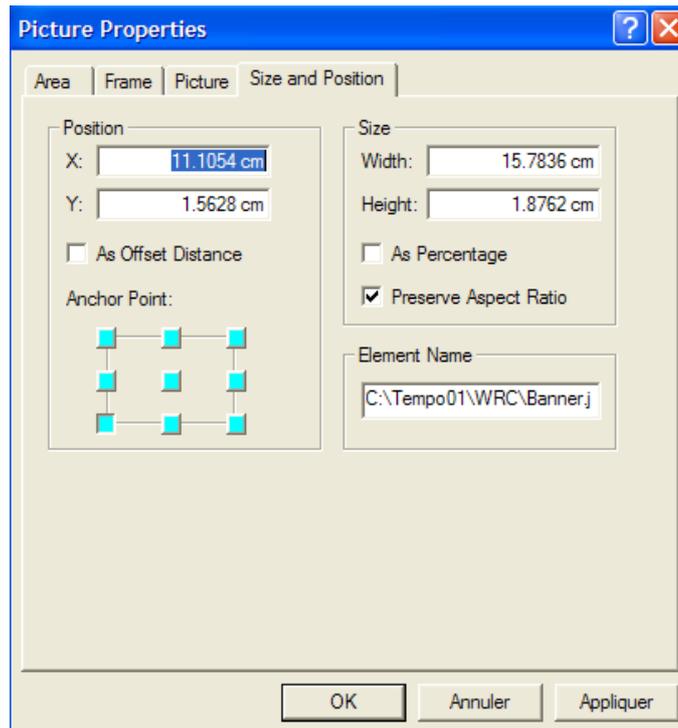
After the creation of the scale bar, *Scale Text Properties* window can be accessed at any moment by a *double-click* on the scale text.

3.5.3.5 Image

An image could be added using the *Insert-Picture...* menu. A window will appear to allow the selection of the image file. Many formats are supported as .jpg, .tif, .gif, .bmp, etc.



At any moment it is possible to access to the *Picture Properties* window using a *double-click* on the image to modify its properties. It could be the image file location, the image position or to set a frame around it.



3.5.3.6 Object

An *Object* could be added to the map using the *Insert-Object...* menu. The window *Insert an object* appears and allows selection of the file associated with the object to insert.

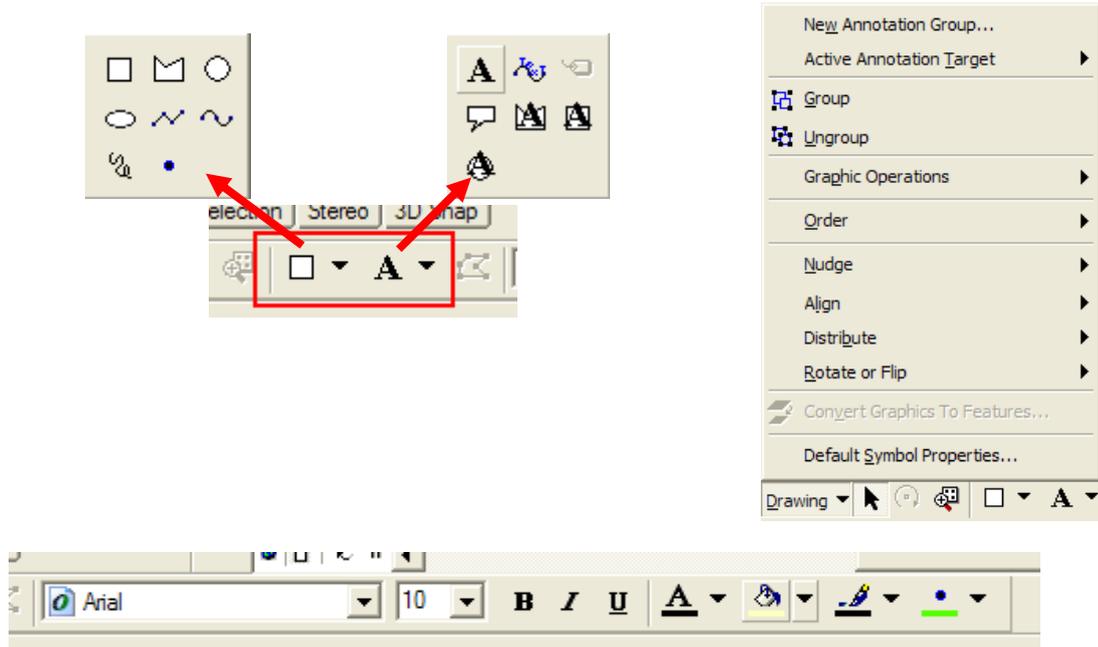
An object could be of different type: *World* document, *Excel* sheet or graph, *Powerpoint* slide, *Autocad* Drawing, *Adobe Acrobat* document, clip video, etc.



3.5.3.7 Graphic element

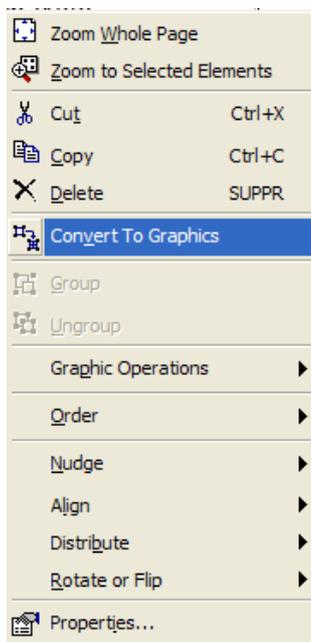
A graphic element is esthetical. It will be used on the map for designing. It could be a text or a shape (line, polygon, point, circle, etc.).

A graphic can be added to the map using *New Rectangle* or *New Text* buttons in the *Draw* toolbar (see section 6.1 for more details). Once it is created, it could be manipulated using options in the *Draw* menu and its properties can be modified using tools in the *Draw* toolbar.



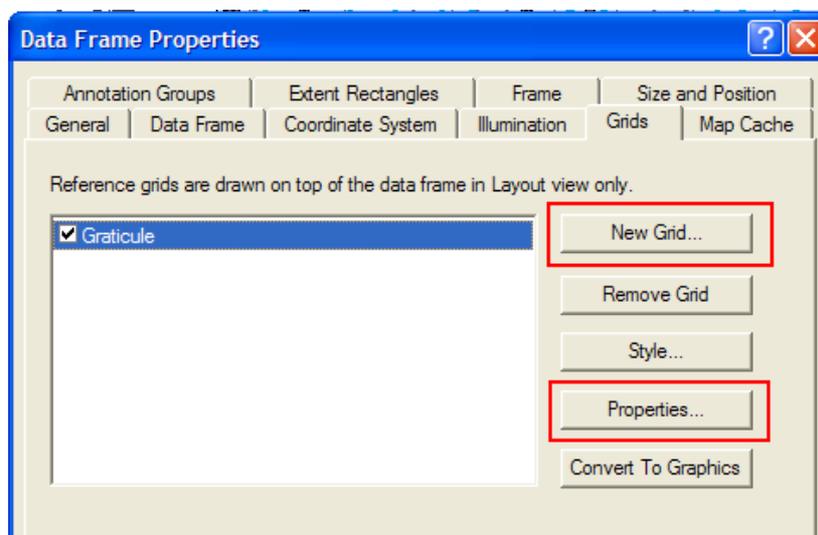
Each complex element as legend, north arrow or scale could be converted to get simple graphic elements. Working with graphics allows a better flexibility (for example, it is impossible to get the standard presentation of a geological legend with *ArcGIS*) but any links are lost when the conversion is applied. This means if a color is changed in the *Table of Contents*, the modification will not be reflect in the legend.

A complex element could be converted in a set of simple graphic elements by à *right-click* on the element and using the *Convert to Graphics* menu. Graphic elements will be grouped together...

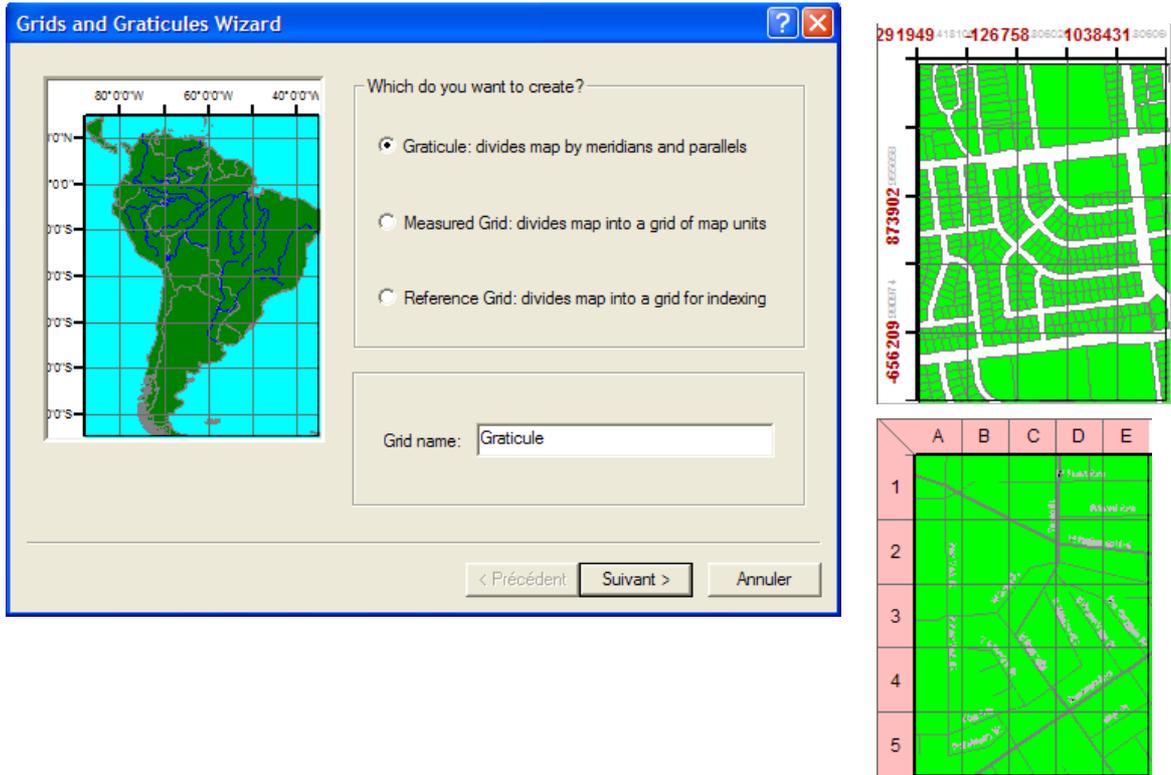


3.5.4 Using a grid

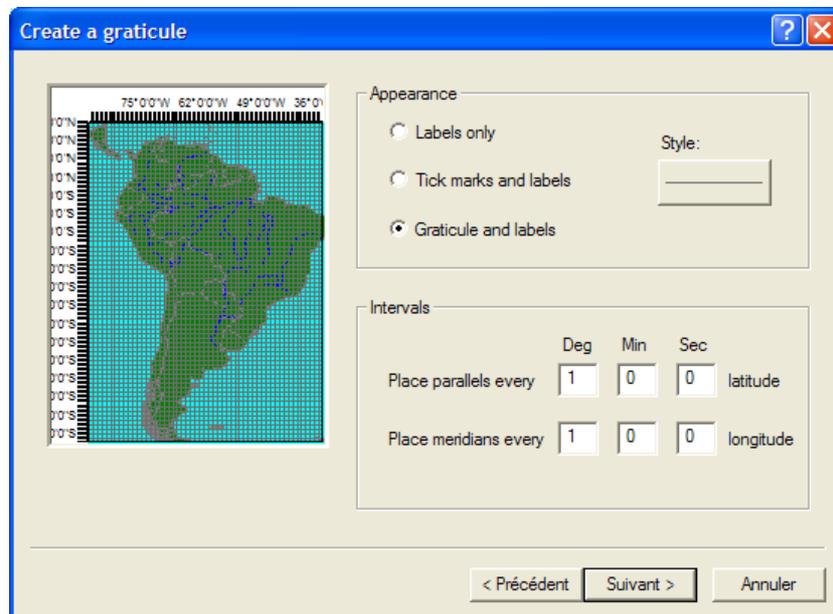
It is possible to set a grid using *Data Frame Properties* window (*right-click* on the Data Frame and use *Properties* menu) under the *Grids* tab. A new grid could be created using the *New Grid* button or an existent one could be modified using the *Properties* button.



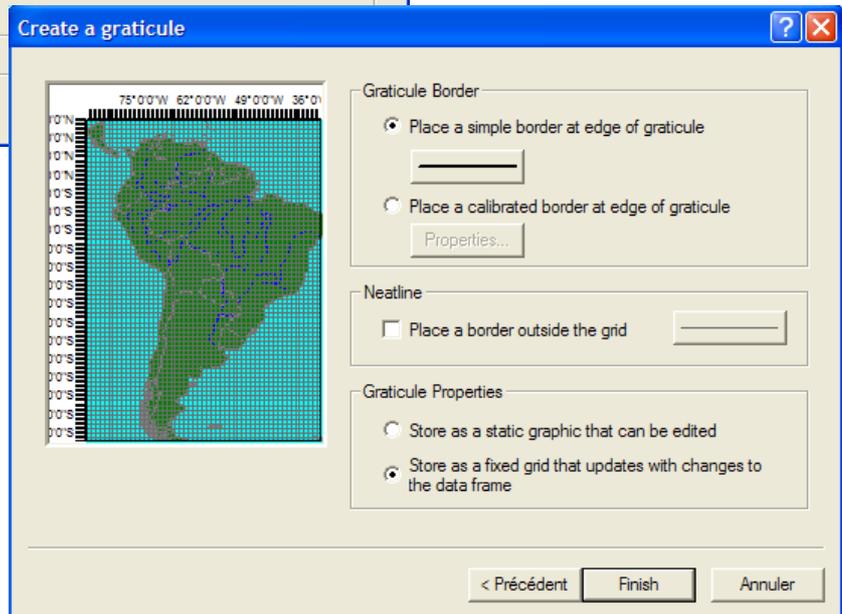
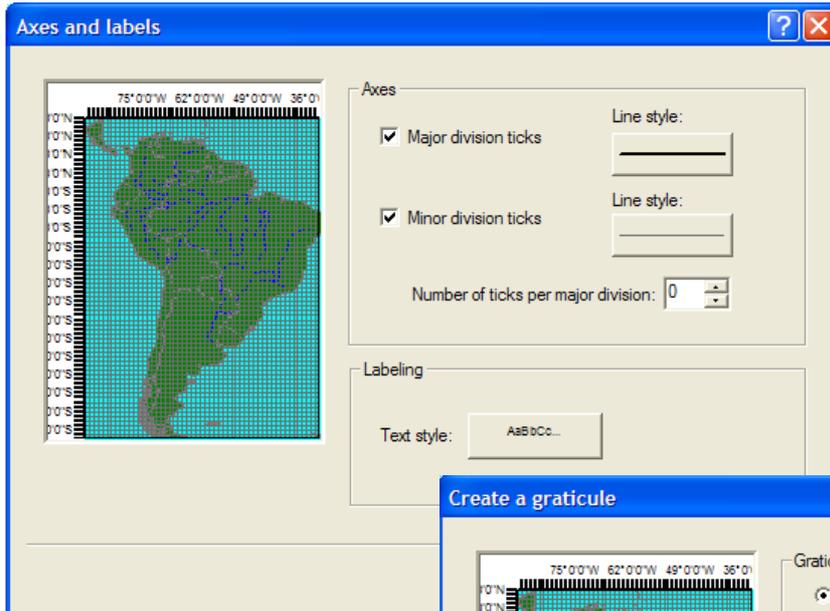
When a new grid is created using the *Grids and Graticules Wizard*, the first step allows selection on which information the grid will be based: *Graticule* (meridians and parallels), *Measured Grid* (map units) or *Reference Grid*.



The second step allows defining what will be presented on the map: *Labels*, *Ticks* or *Graticule*. The color of linear element could be changed to ensure the map is readable. It will also allow defining parallels and meridians intervals.



The third step allows definition of major and minor divisions and the labelling, and the final step allows setting properties regarding border and the state of the graticule (could be set as independent graphic elements).



4. ARCHYDRO GROUNDWATER TOOLBAR

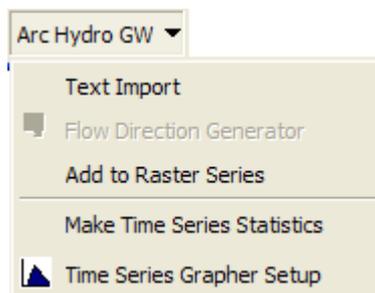
The *ArcHydro Groundwater* toolbar is a freeware develop by *Aquaveo* (www.aquaveo.com). The toolbar present three menus, *ArcHydro GW*, *Subsurface* and *ApUtilities*, and many tools useful for the management and analysis of groundwater data.



Two other toolbars are offered by *Aquaveo* but are not free. With the first one, *MODFLOW Analyst*, it is possible to create, archive, and visualize modflow models within *ArcGIS*. With the second one, *Subsurface Analyst*, it is possible to create and visualize both 2D & 3D geologic models, starting with classification and visualization of borehole logs, creation and editing of cross sections, and generation of 3D geosections and geovolumes.

4.1 *ArcHydro GW* menu

This menu presents five submenus:



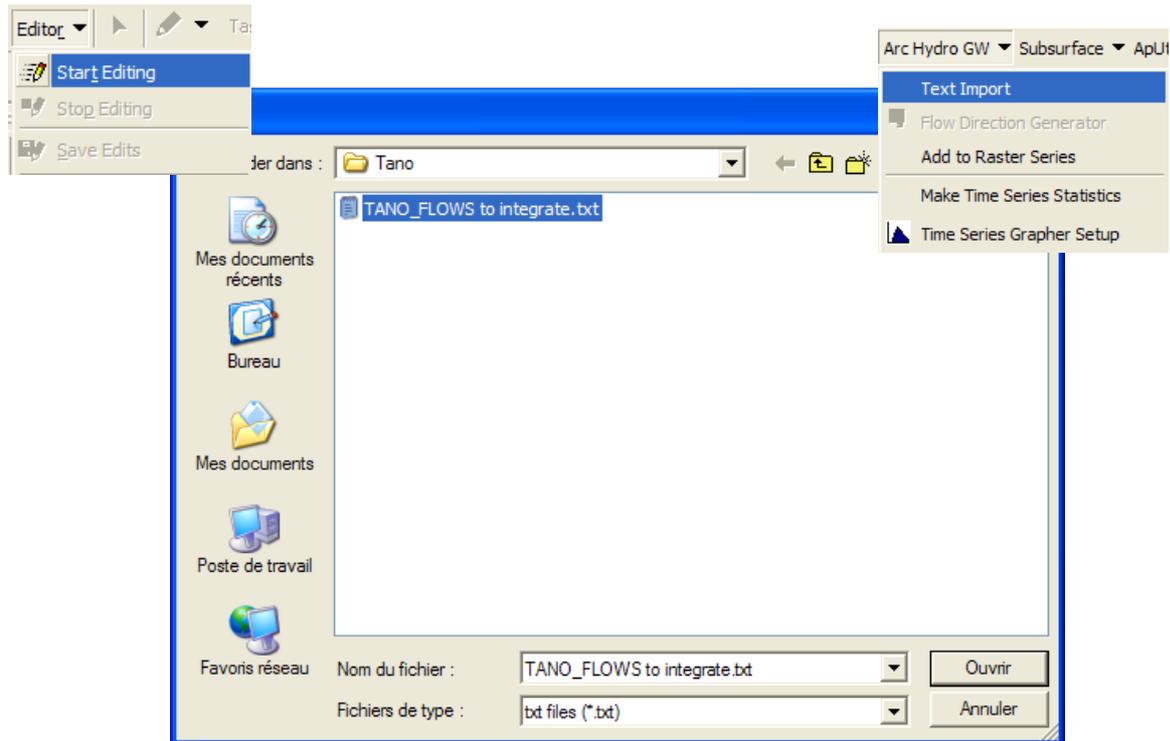
4.1.1 *Text Import* menu

The *Text Import* menu is one of the most important tools of the *ArcHydro Groundwater* toolbar. It allows the integration of data in the WRC Groundwater Database using *Delimited text* files. This way, information could be prepared in *Excel* without using *ArcGIS*. This method presents the advantage that many persons could input data at the same time without using an *ArcGIS* licence and they do not need to be familiar with the *ArcGIS* utilisation.

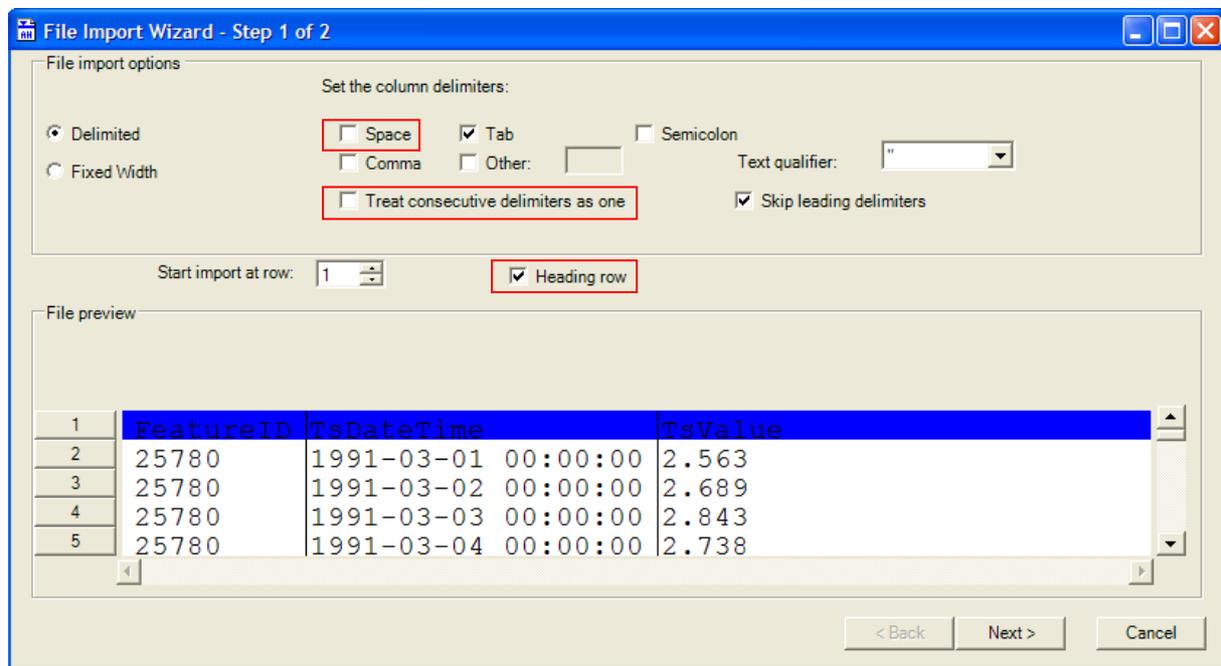
Templates in *Excel* format have been developed to help the integration of output. Those templates are based on the WRC database table's structure. When a field has a domain values, a drop-down list has been set to the column in *Excel*. Of course, if a domain is modified in *ArcGIS*, the drop-down list has to be updated to reflect changes of the database.

Once the input is completed in *Excel*, results must be saved in a *Delimited text* format using the *Save as* menu. It is now time to use the menu *Text Import* in the *ArcHydro Groundwater* toolbar.

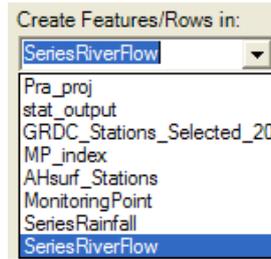
An edit session must be started first. Otherwise, the *Text Import* tool will run and never tell data could not be input and the target table will not be updated.



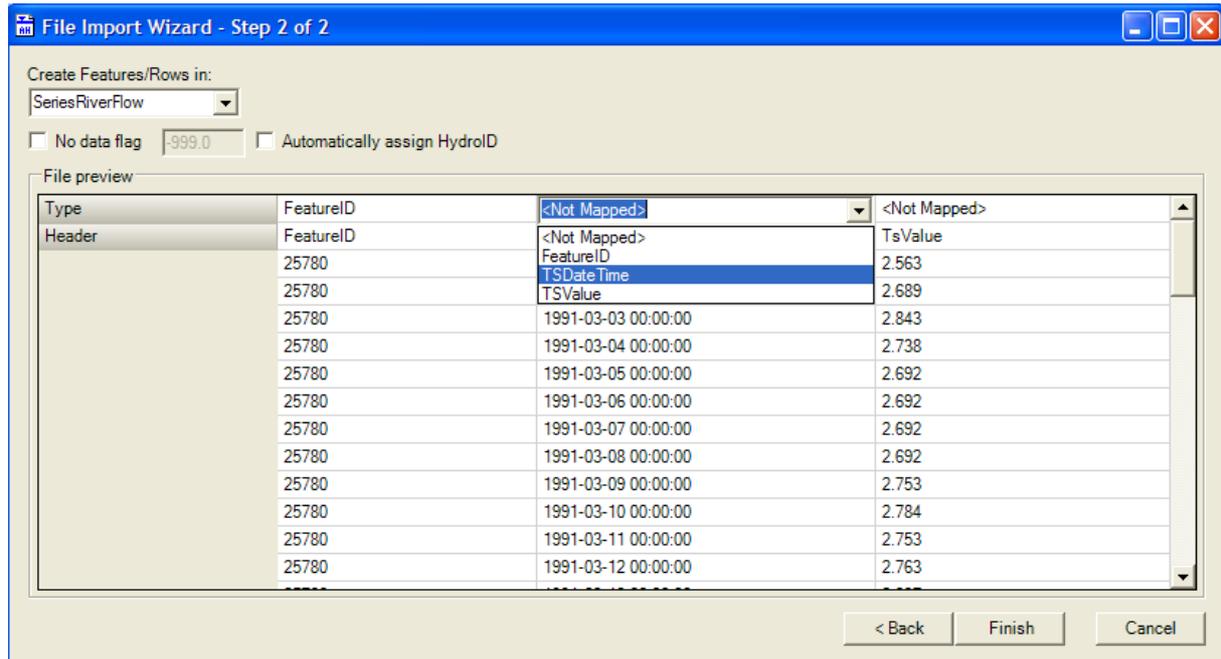
In the *File Import Wizard – Step 1 of 2* windows, the delimited file is presented. Some options have to be modified. *Space* and *Treat consecutive delimiters as one* options have to be unchecked and the *Heading row* option has to be checked.



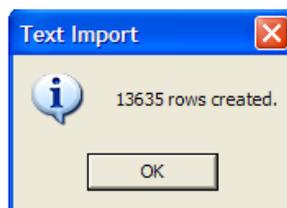
In the *File Import Wizard – Step 2 of 2*, the first step is to select the target table in the *Create Features/Rows in:* drop-down list. The target table must be presented in the .mxd file otherwise it will not appear in the drop-down list.



If *Excel* column name fit with the target field names, the wizard will match them automatically. Otherwise, they have to be matched manually.



When the match is perfect, only click on the *Finish* button and information will be input in the target table. A message will appear to indicate the number of rows added to the table.



If the information to input is related to features, for example Well, the *Delimited text* must have X and Y fields and the option *Automatically assign HydroID* in the *File Import Wizard – Step 2 of 2*

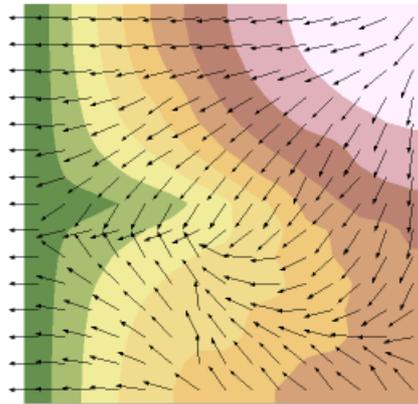
If a column contains *NullValue* on the first row, the tool has problem to recognize the beginning of a new column. To correct the problem, the *NullValue* has to be replaced by a space (a space is a character and the system recognize it as a value).

Sometimes, an error message relative to *Spatial Analyst* appears at the end of the treatment but this does not affect the results.

4.1.2 Flow Direction Generator *and* Add to RasterSeries menus

These two menus need a grid data input and they are not applicable in the WRC environment.

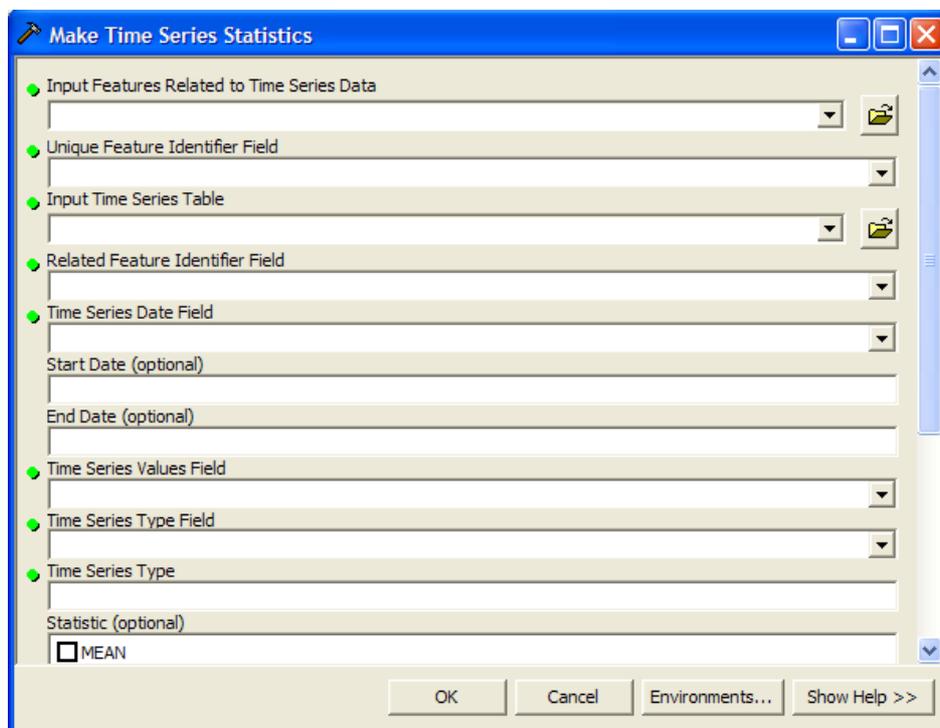
The *Flow Direction Generator* tool creates a new graphics layer covering the extent of a raster, showing flow direction arrows at a specified interval.



Add to Raster Series tool loads a raster dataset into a raster catalogue and attributes the raster with start and end date/time. The start and end date/time represent the time period of the data stored in the raster, and can be used for animating a series of rasters stored in the catalogue.

4.1.3 Make Times Series Statistics menu

This menu gives a direct access to the *Make Time Series Statistics* tool from *ArcToolBox*. Many parameters are necessary.



This tool is a combination of *Summarize*, *Selection* and *Extraction* operations. It will calculate statistics for each unique feature (summarize) between a starting and ending dates (selection) and will produce an output layer (extraction).

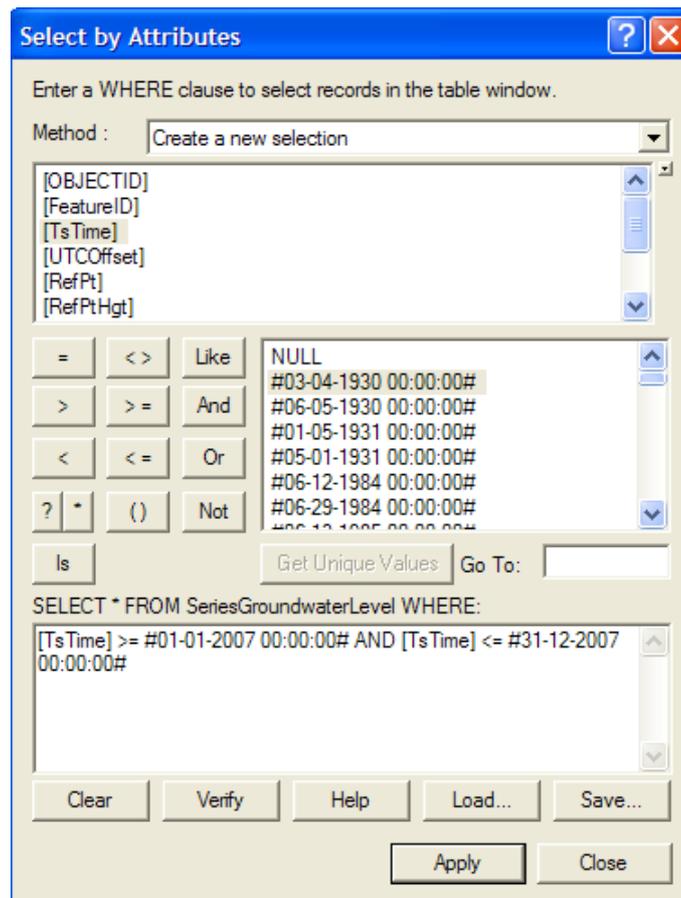
This tool presents a major problem with the WRC Groundwater Database Structure. It has been develop to be use with a unique *TimeSeries* table using a *Time Series Type* field and the WRC Structure does not have this field. Every type of Time Series has been separated in different tables (*SeriesGroundWaterLevel*, *SeriesGroundWaterQuality*, *SeriesPumpingTest* and *SeriesStepDrawDownPumpingTest*).

Time Series Type Field and *Time Series Type* parameters are necessary and that means the tool is not usable with the WRC database structure.

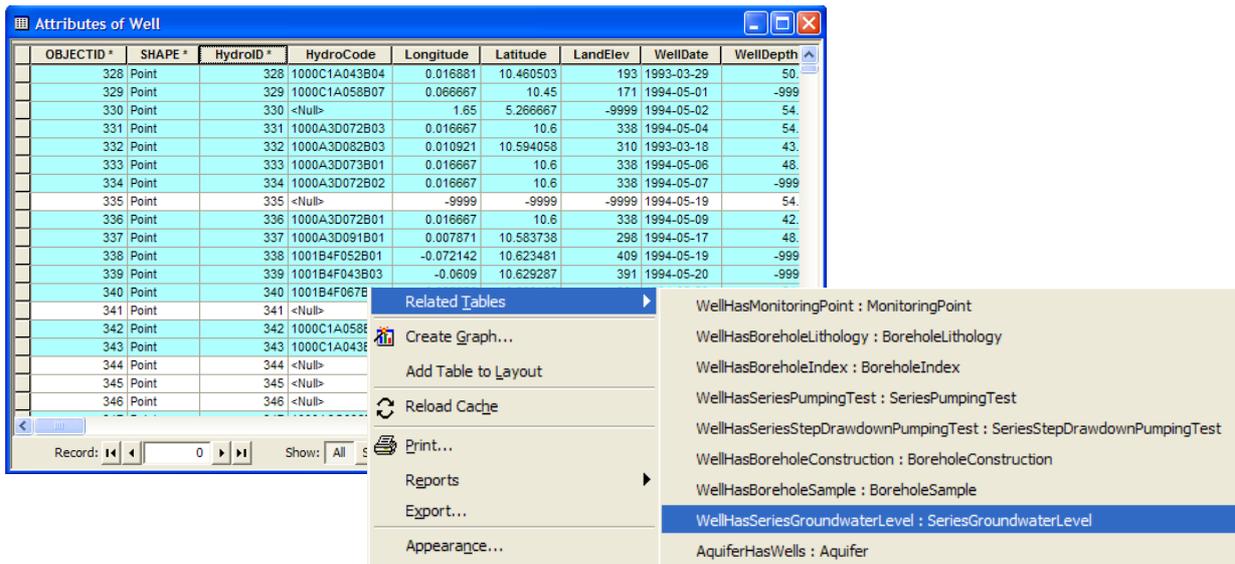
Otherwise, statistics could be realized using the manual method. This option has two major advantages. Any kind of selection (spatial, manual or with attributes) could be applied to restraint the treatment instead of Start and End dates, and statistics could be calculated on many field and not only on the *Time Series Values* as the tool propose it.

The only disadvantage is the obligation to merge manually the statistic result table with corresponding features.

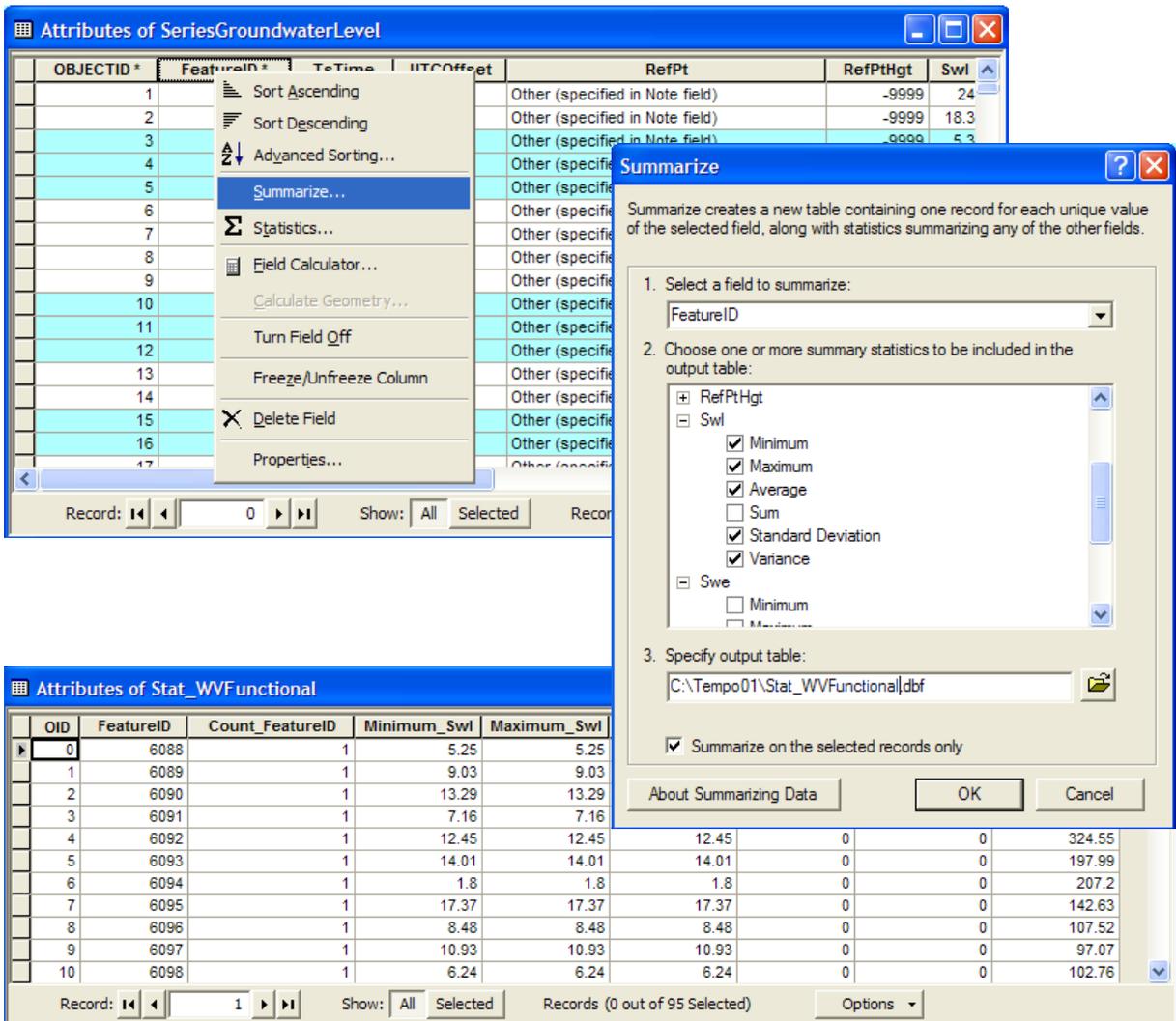
To obtain statistics using the manual method, the user has to work first on the series table. If needed, a selection has to be applied on the table. For example, to select records for a certain period in *BoreholeLog* table, the *Select by attributes...* menu could be used.



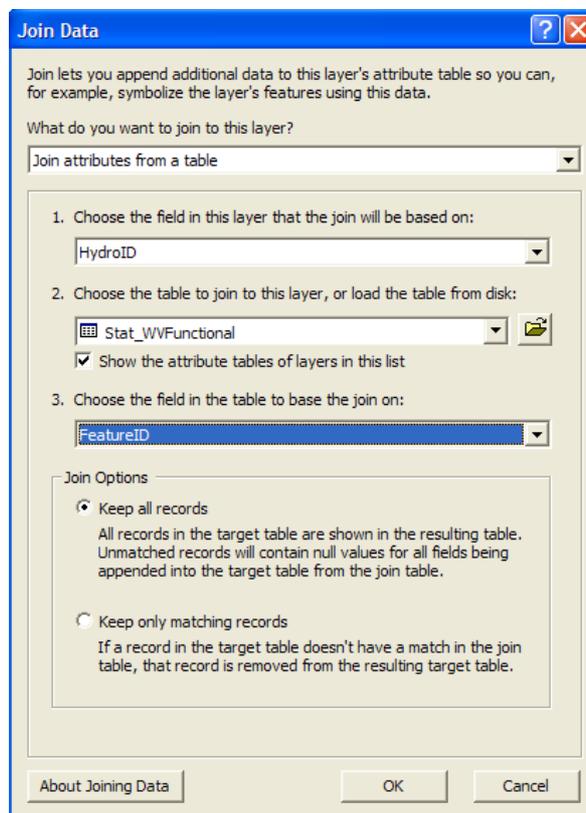
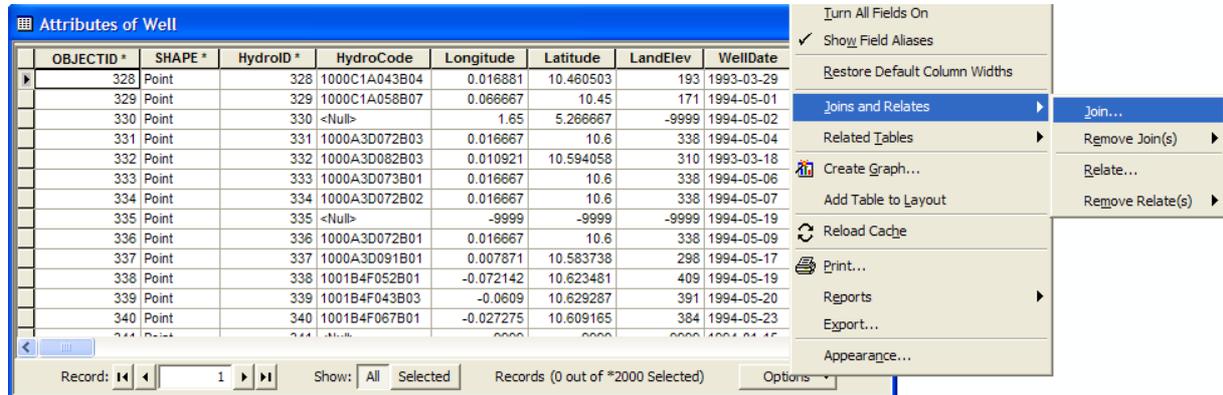
As another example, the target could be to obtain statistics on functional boreholes only in the White Volta basin. A spatial selection will be used to select well features inside the limit of the White Volta basin and an attributes selection will be used to select a subset of well with the *WellState* equal to *Functional*. The selection has now to be transferred to the series table using the *Related Tables* menu and the corresponding relation.



Once the selection is done, a summarize operation has to be done on the *FeaturesID* field. The system will operate a concatenation on every record of the same featuresID and calculate statistics asked in the *Summarize* windows. A result table will then be created.



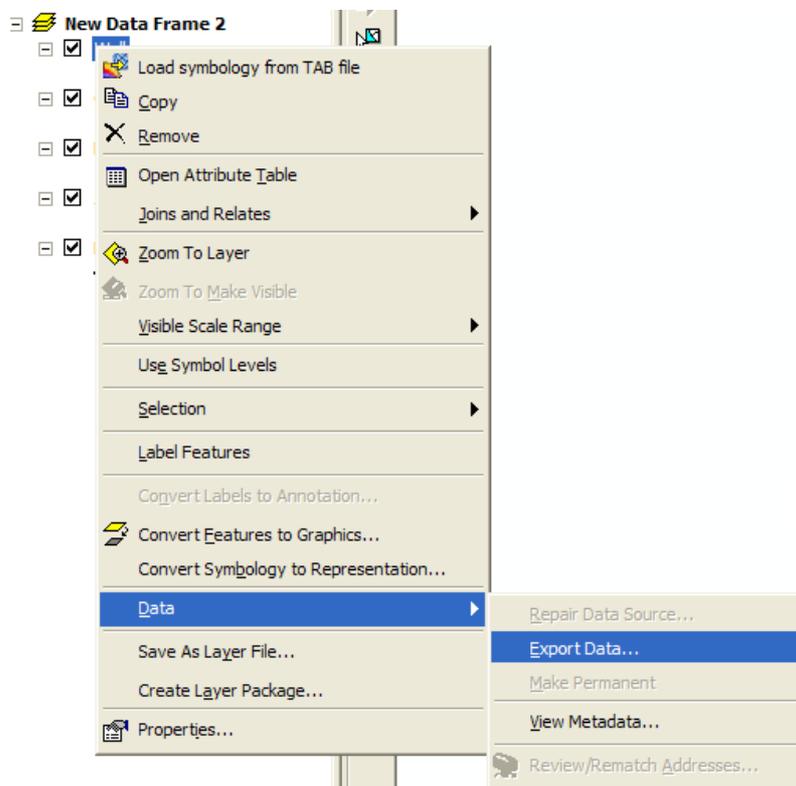
To create an output layer, the statistic result table has to be joined with the basic feature layer. In the example, the feature layer is *Well*.



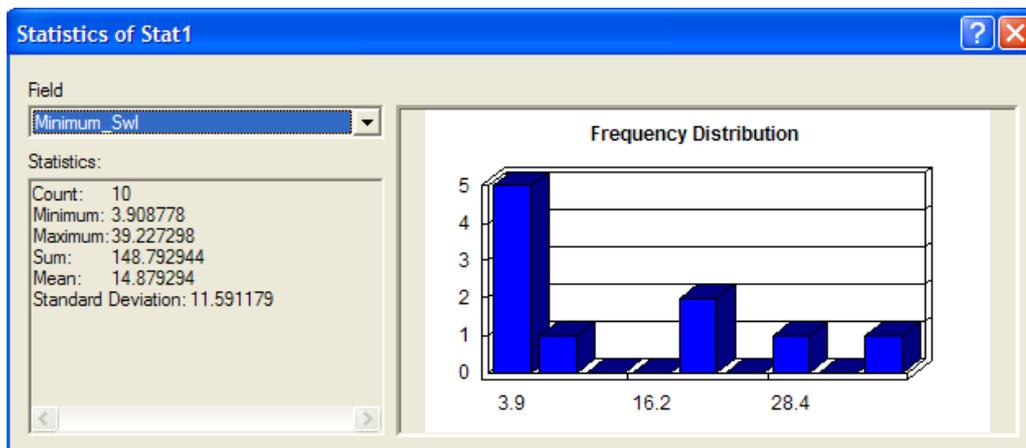
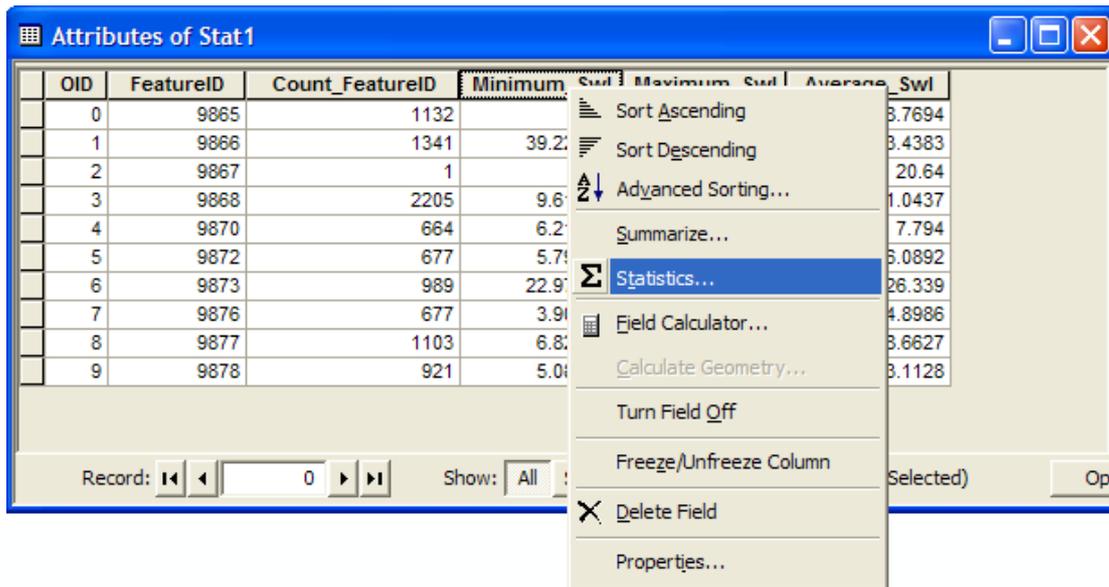
After the join, fields from the statistic result table are joined at the end of the *Well* table. Records with a value identify wells used for the analysis and have been selected.

Count_FeatureID	Minimum_Swl	Maximum_Swl	Average_Swl	StdDev_Swl	Variance_Swl	Average_Sv
1	35.3	35.3	35.3	0	0	
1	31.8	31.8	31.8	0	0	
1	24.2	24.2	24.2	0	0	
1	23.3	23.3	23.3	0	0	
1	22.6	22.6	22.6	0	0	
1	22.1	22.1	22.1	0	0	
1	21.6	21.6	21.6	0	0	
1	20.5	20.5	20.5	0	0	
1	20.14	20.14	20.14	0	0	
1	19.83	19.83	19.83	0	0	
1	18.6	18.6	18.6	0	0	
1	18.54	18.54	18.54	0	0	
1	18	18	18	0	0	
1	17.7	17.7	17.7	0	0	

Statistics information and selected features will be merged permanently using the *Data-Export Data...* menu.



Statistics could also be calculated for a whole field with a *right-click* on the field to analyse and using the *Statistics...* menu.

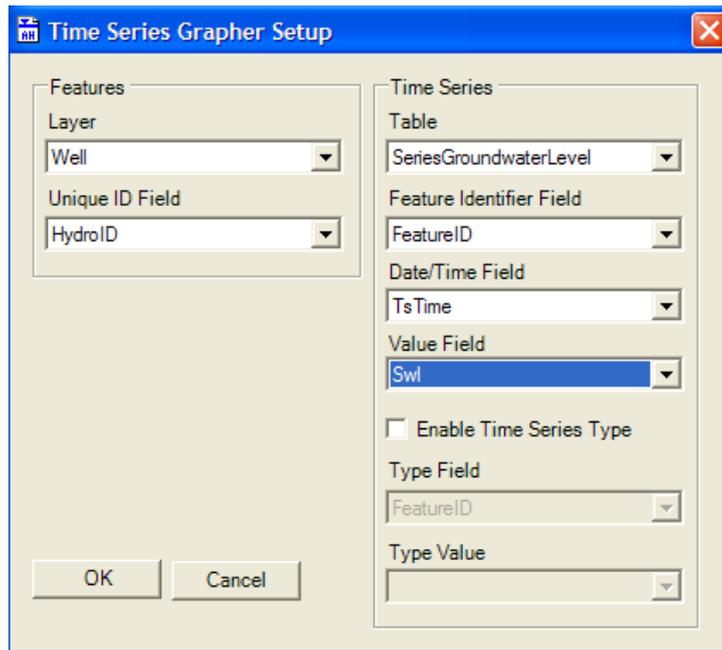


4.1.4 Time Series Grapher Setup menu

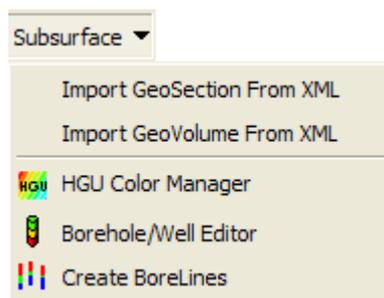
The *Time Series Grapher Setup* window allows the user to assign parameters for the presentation of Time Series graphics.

In the WRC Groundwater Database, Time Series are linked to the *Well* layer using the *HydroID* except for *SeriesGroundWaterQuality* which is linked to the *BorelineSample* layer. The table of the Time Series to be presented has to be selected and fields corresponding to the FeaturesID (allows the link with the *HydroID* of the *Well* Layer), the time and the value use for the graphic has to be set. The WRC Groundwater Database Structure does not have a Time Series Type so the option *Enable Time Series Type* is not applicable.

The *Time Series Grapher Setup* window also appears automatically when the *Interactive Time Series Grapher* tool is selected. So it is recommended to use this option instead of the *Time Series Grapher Setup* tool because for an unknown reason parameters are not saved using this option.

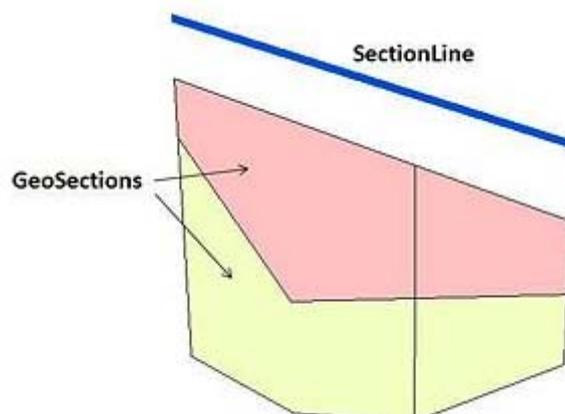


4.2 Subsurface menu

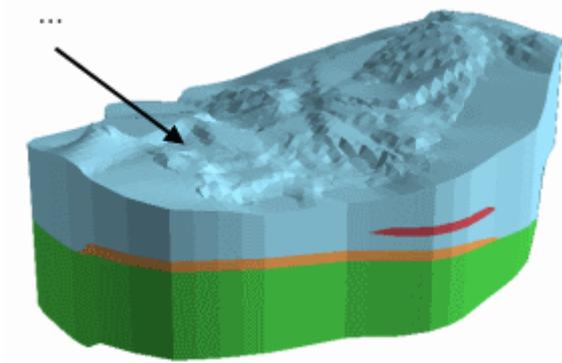


4.2.1 Import GeoSection from XML and Import GeoVolume from XML menus

This tool imports 3D GeoSection features (3D multipatches) from an XML file. The XML file is structured as a set of SectionLines and GeoSections. The geometry of the SectionLine and GeoSection objects is defined by a set of vertices, where each vertex is defined by X, Y, and Z coordinates.



The tool imports 3D GeoVolume features (3D multipatches) from an XML file. The XML file is structured as a set of vertices and triangles.

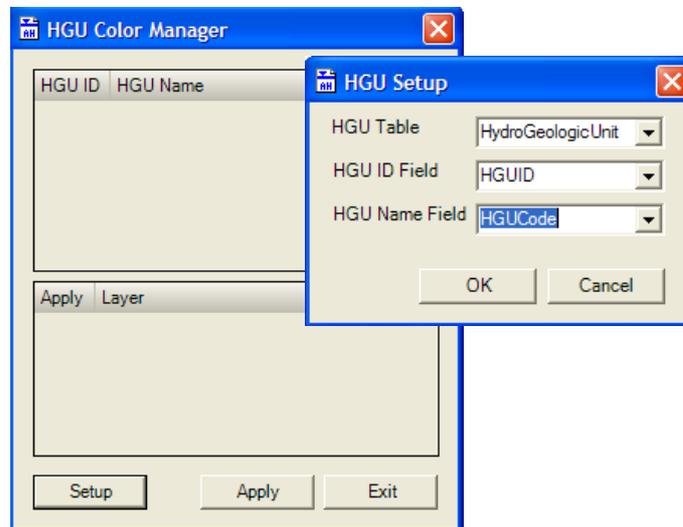


4.2.2 HGU Color manager menu

The *HGU Color manager* allows the assignment of a color for each HGU value present in the *HydroGeologicUnit* table. This enables users to quickly symbolize complex 3D scenes and also enables visualization of groups of hydrogeologic units with the same symbology.

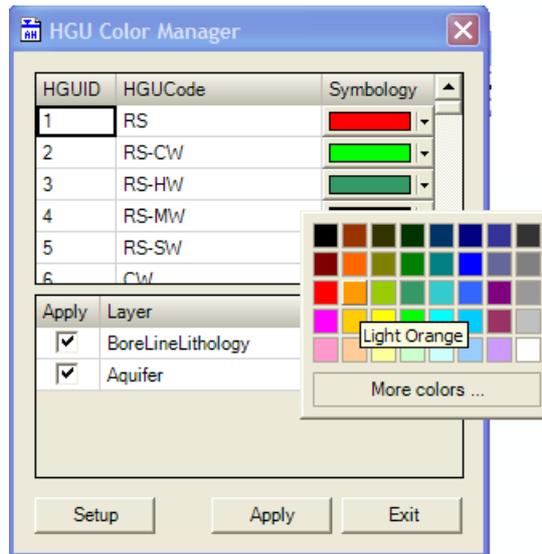
To access the *HGU Color manager* menu, the user has to load one or more feature layers and the *HydroGeologicUnit* table.

When the *HGU Color manager* is open, click on the *Setup* button to access the *HGU Setup* window and select *HydroGeologicUnit* as a *HGU table*, *HGUID* as a *HGU ID field* and *HGUCode* as *HGU Name field* then click on the *OK* button.



The *HGU Color manager* is now ready for color assignment. Color setting will be applied to the layer selected with a check box. Layers presented are those ones who have an *HGUID* attribute.

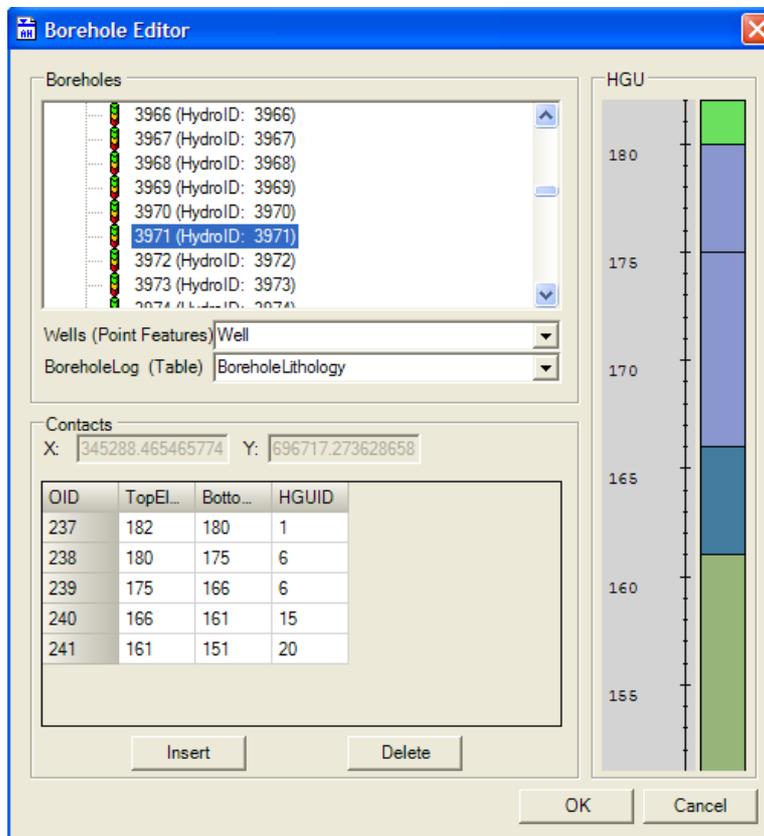
When all colors are assigned, the user should click the *Apply* button to save the setting.



This color assignment is very interesting, for example, to visualize the *BoreLineLithology* layer in *3D Analyst*.

4.2.3 Borehole/Well Editor menu

The *Borehole/Well Editor* allows a 3D visualisation of a well component. The tool uses the *From Depth* and *To Depth* fields of the *BoreholeLog* table to generate a column describing the length of components.



In the WRC Groundwater database, *BoreholeLog* tables could be *BoreholeConstruction*, *BoreholeLithology* or *BoreholeSample*. For this last one, the tool is not really interesting because there is only one interval.

To get information on intervals and a representation in the HGU part of the *Borehole Editor* window, a well must be selected. If there is no corresponding information in the *BoreholeLog* table, the HGU part will stay empty and no interval will appear.

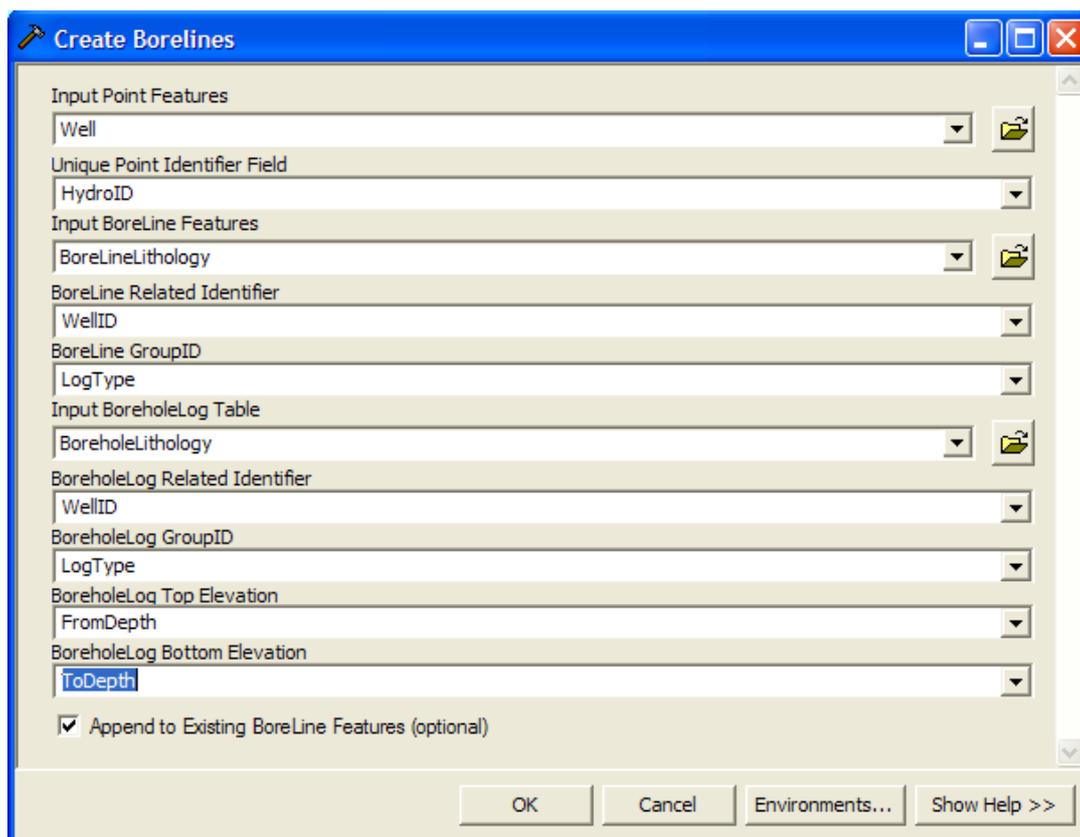
Intervals could be deleted or inserted and Interval values could be modified. But it is not recommended to use this tool to do this. Values in the table are not correctly set. To realize an update, it is better to modify values directly in the table.

It is then recommended to use this tool only to visualize the 3D components of a borehole.

4.2.4 Create BoreLines menu

This menu gives a direct access to the *Create Borelines* tool from *ArcToolBox*. Many parameters are necessary.

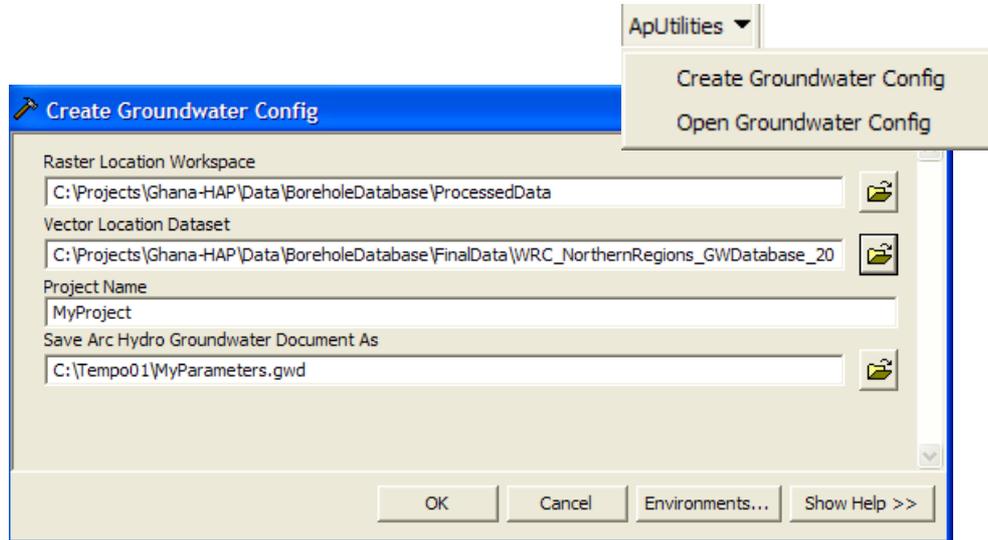
This tool will use, for example, the *BoreholeLithology* table to generate a features layer of 3D lines created using *FromDepth* and *ToDepth* fields. In 2D, features are represented by points. To see lines, *3D Analyst* is necessary.



This tool has to be used every time an update is necessary. If information changes in the *BoreholeLog* table, 3D lines have to be regenerated (or added). New boreline information could be appended to the existing *Boreline* layer.

4.3 ApUtilities menu

This menu is composed of two submenus, *Create Groundwater Config* and *Open Groundwater Config*. Those two options are used to save and load parameters related with the *ArchHydro Groundwater* toolbar for example, the *Vector Location Dataset*.



4.4 ArchHydro tools

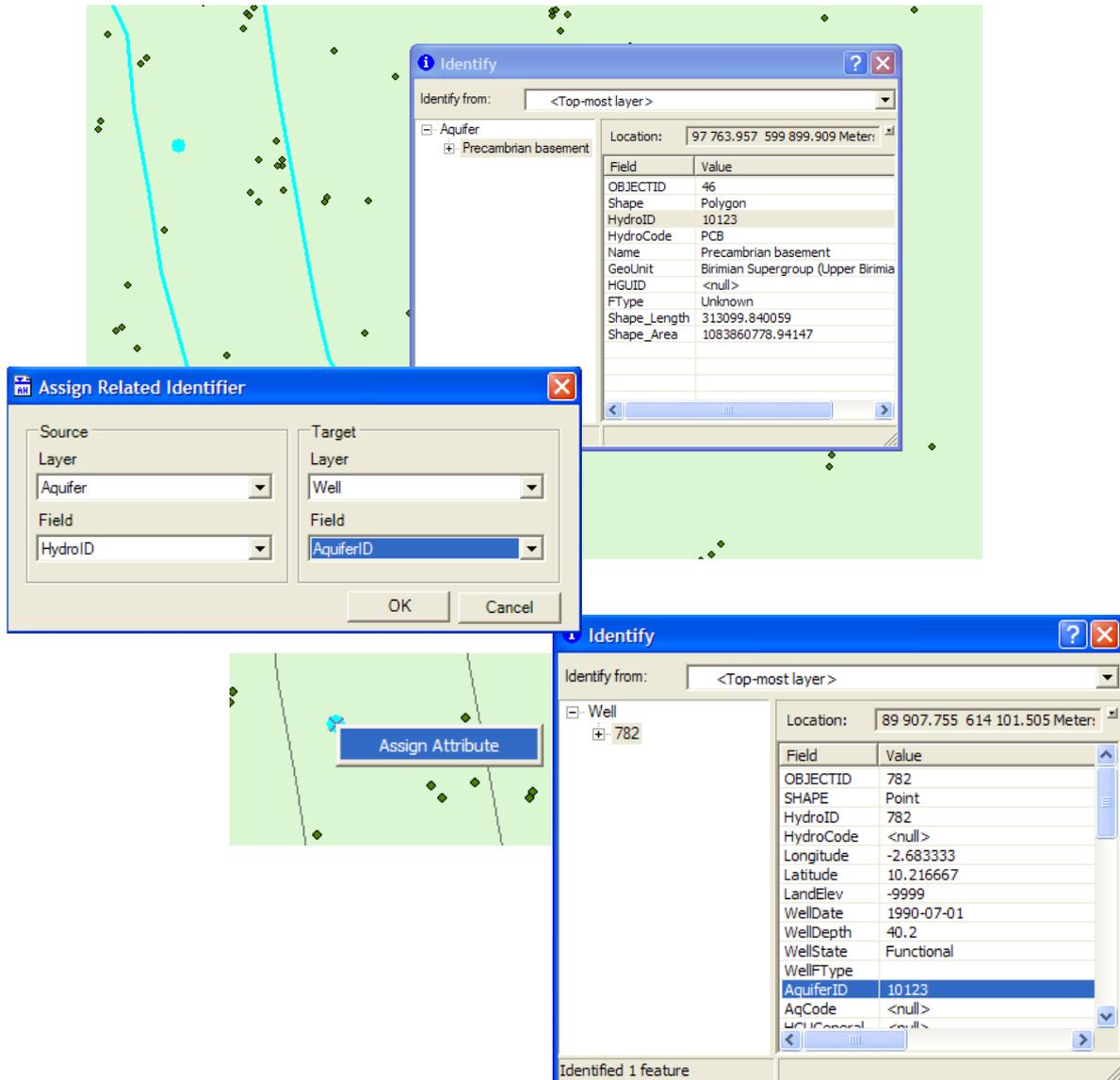


4.4.1 Assigned Related Identifier tool

The *ArchHydro Groundwater* data model includes relationships between features, which are based on key fields. For example, well and aquifer features are related through the *HydroID* and *AquiferID* key attributes. The *Assign Related Identifier* tool simplifies the matching up of these IDs interactively, by assigning the value of one field in one layer to another field in another layer.

An Edit session must be started first. Otherwise, the value will not be assigned in the target layer. Using the *Assigned Related Identifier* tool, the target feature has to be selected and using a *right-click*, the menu *Assign Attribute* has to be select.

In the WRC Groundwater database, this tool is also very useful to assign the *HydroCode* value in the *Well* table using the Index layer as the source.



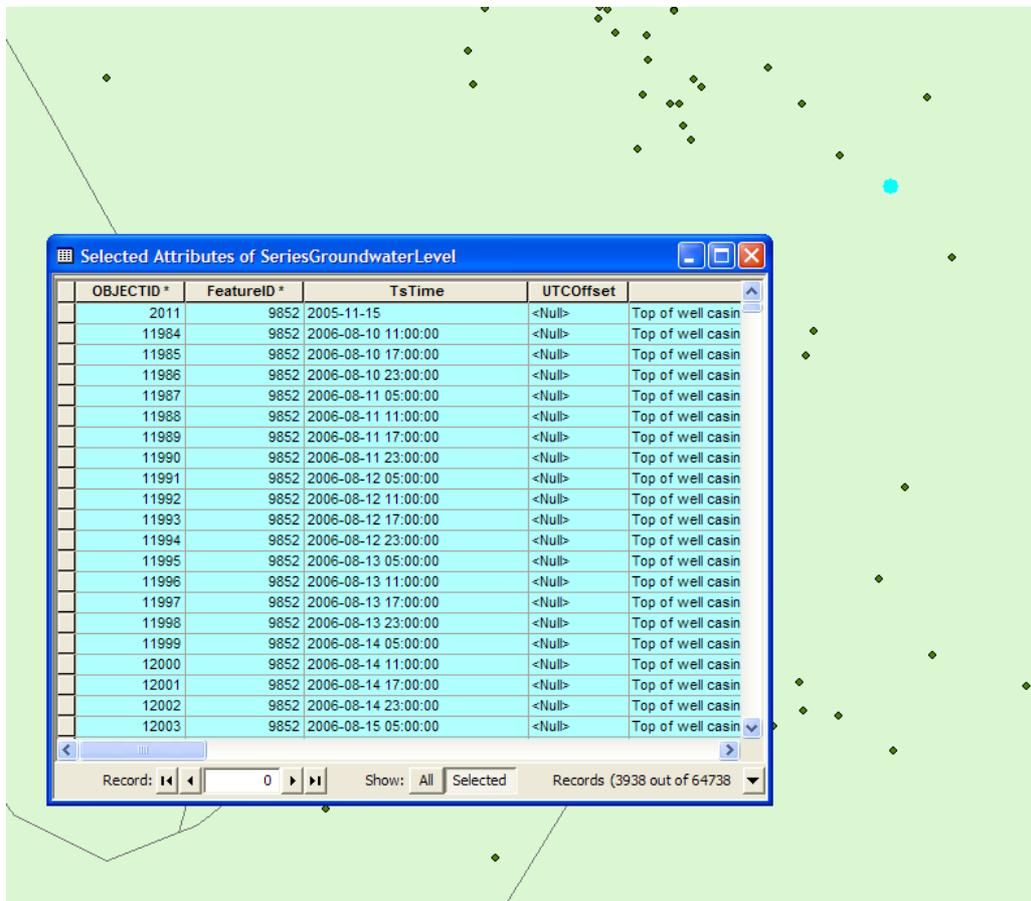
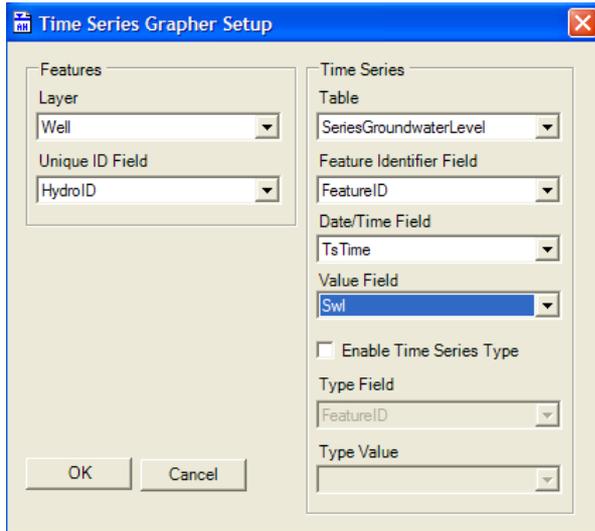
4.4.2 Interactive Time Series Grapher tool

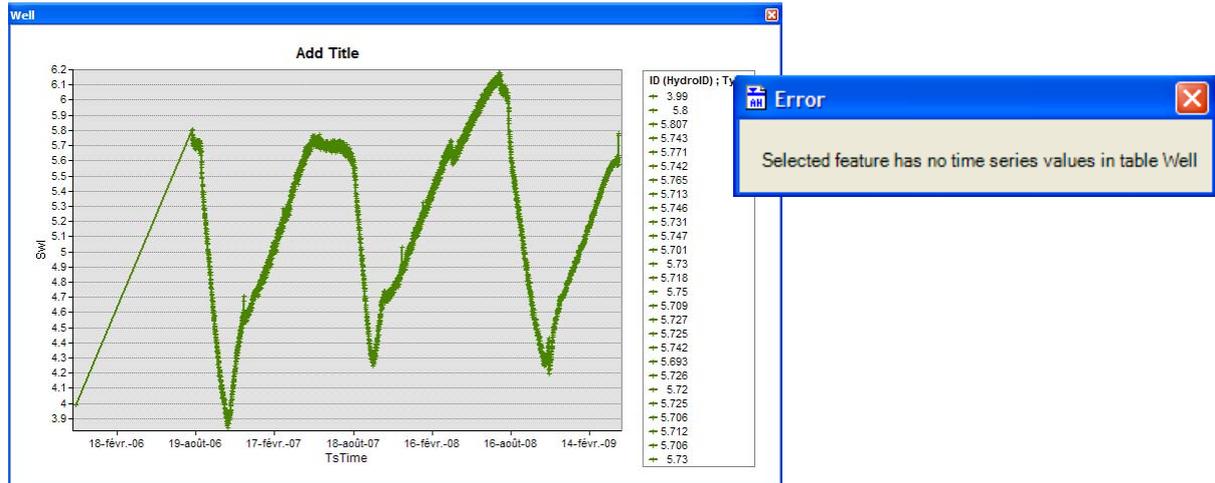
The Interactive *Time Series Grapher* tool allows the user to generate a series graph by clicking on a feature.

In the WRC Groundwater Database, *SeriesGroundWaterLevel*, *SeriesPumpingTest* and *SeriesStepDrawDownPumpingTest* are linked to the *Well* layer using the *HydroID*. *SeriesGroundWaterQuality* is linked to the *BorelineSample* layer.

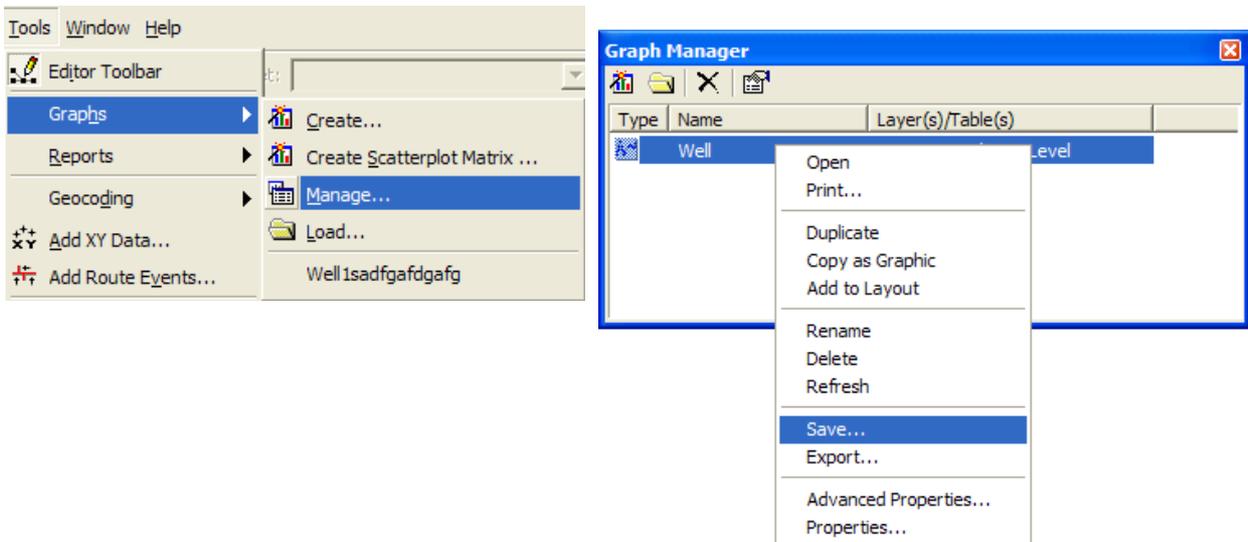
When the *Interactive Time Series Grapher* tool is selected, the *Time Series Grapher Setup* window appears automatically.

Depending on what kind of series have to be presented, parameters have to be set. When the *OK* button is selected, the user can click on a feature, for example *Well*. If this well has Time Series, a graph is plotted. Otherwise an error message will appear.





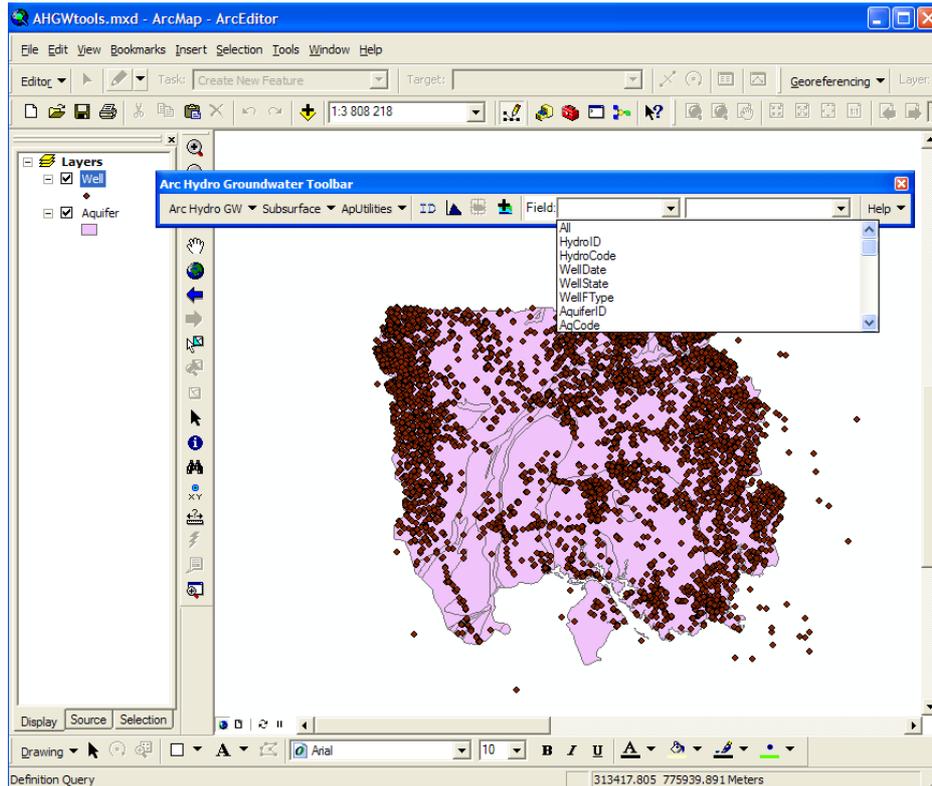
A graph is created and could be manage in the *Graph Manager*. Only one graph could be created by layer. To generate another graph, the actual graph must be deleted first. Otherwise, no graph will appear.



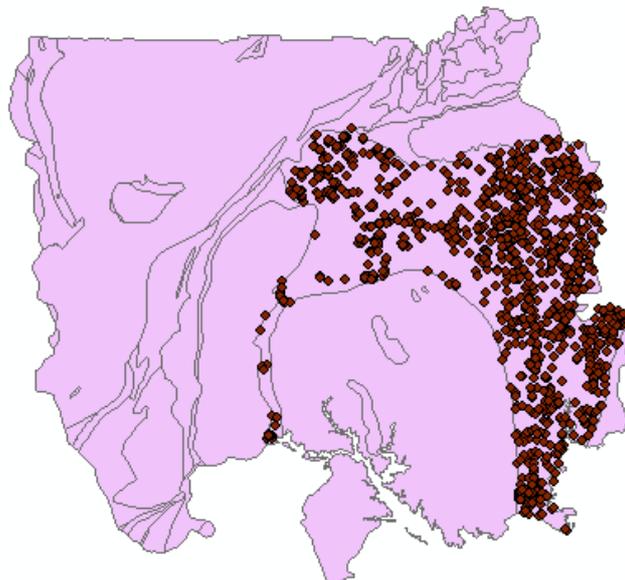
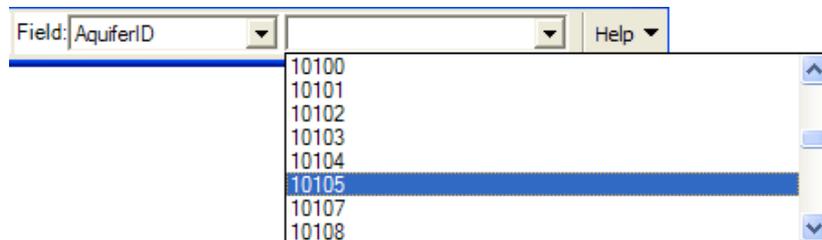
4.4.3 Toolbar Filter tool

A definition query is used to filter a layer using attributes and values in the layer table. It could be realized quickly in *ArcMap* or *ArcScene* by using the Arc Hydro Groundwater toolbar filter.

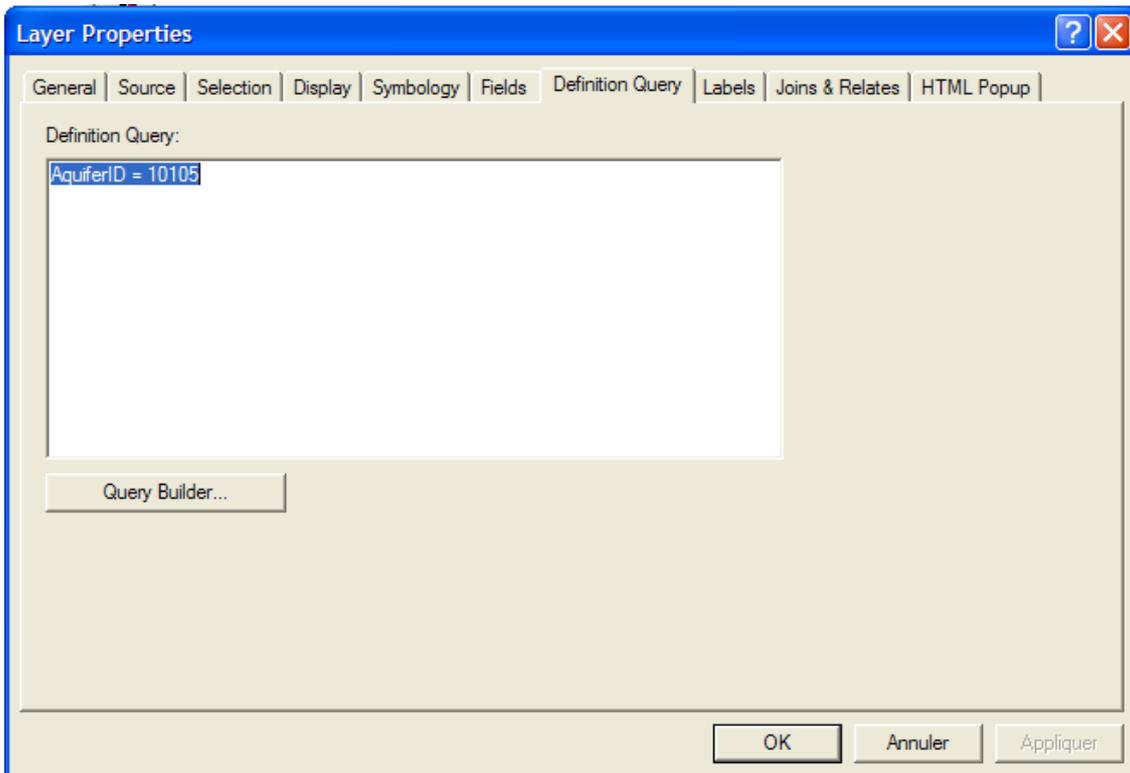
The *Toolbar Filter* tool will be enabled **only if a layer is selected in the table of content**. For example, if the layer *Well* is selected, the first drop-down list presents fields in the *Well attributes* table.



When a field is selected in this drop-down list, for example *AquiferID*, the second drop-down list is updated to present values present in this field. When a value is selected, only features with this value are presented.



The definition query is based on unique values for a selected field in the feature layer. The tool allows a simple definition query but if a more complex query is necessary, the filter could be set in the *Layer properties* window where the definition query is stored.



4.4.4 2D Cross Section tool

This tool allows the user to generate a 2D cross section. It could not be used because it is linked to *Subsurface Analyst* module and this one is not licensed.



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