DEPLOYMENT, MAINTENANCE AND FURTHER DEVELOPMENT OF SPATSIM-HDSF

Volume 1

SPATSIM-HDSF Modelling Framework

Report to the
WATER RESEARCH COMMISSION

by

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PREFACE

The work resulting from WRC project K5/1870 titled "*Deployment, Maintenance and Further Development of SPATSIM-HDSF*" has been published in three separate printed volumes and a DVD (accompanying Volume 1) as follows:

- Volume 1: *SPATSIM-HDSF Modelling Framewor*k
  - Main Report
  - Appendix A: *SPATSIM-HDSF: User Manual*
  - Appendix B: *SPATSIM-HDSF: External GIS Tools*
  - Appendix C: *TSAnalysis Tools: User Manual*

- Volume 2: *National Database of Ecological Reserve and EWR Management*
  - Appendix D: *National Database of Ecological Reserve and EWR Management: Report and User Manu*al
  - Appendix E: *National Database of Ecological Reserve and EWR Management: Step-by-Step Training Guide*

- Volume 3: *ACRU Agrohydrological Model*
  - Appendix F: *ACRU4 User Manual: User Interface And Tutorials*
  - Appendix G: *ACRU4 User Manual: Running ACRU From SPATSIM-HDSF*

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    - H.7 SPATSIM-HDSF Workshop October 2011 – Report
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    - I.1 SPATSIM-HDSF: Software
    - I.2 SPATSIM-HDSF: User Manuals and Training Materials
    - I.3 *ACRU*: Software
    - I.4 *ACRU*: User Manuals and Training Materials

EXECUTIVE SUMMARY

BACKGROUND

The National Water Act (NWA, 1998) of South Africa (Act 36 of 1998) aims to ensure that South Africa's water resources are managed and used in an equitable and sustainable manner for the benefit of all. The National Water Act (NWA) requires a different approach to managing the nation's water resources and the concept of integrated water resources management (IWRM) is central to this approach (Pollard and Du Toit, 2008). IWRM requires water managers to consider hydrological, ecological, economic, political, social and institutional aspects of water resources. To implement IWRM, water managers require integrated modelling tools to provide information that can assist in making managements decisions. There are two aspects of integrated modelling that have received increasing attention in recent years: (i) the coupling of models representing different water resource domains, and (ii) the development of integrated modelling frameworks or decision support systems. These integrated modelling frameworks typically include a common data repository, common data editing tools, common spatial and temporal data visualisation and analysis tools, and a collection of framework compatible models that make use of these common tools.

The Spatial and Time Series Information Modelling (SPATSIM) software is a hydrological modelling framework, initially developed by the Institute for Water Research (IWR) at Rhodes University in South Africa, and described as an integrated hydrology and water resource information management and modelling system (Hughes, 2005; IWR, 2011). Hughes (2002) explains that SPATSIM integrates spatial and time series information in a flexible modelling framework that includes a variety of data storage, retrieval, analysis and display options suitable for the application of a range of different framework compatible models. The SPATSIM modelling framework was further developed as part of Water Research Commission (WRC) project K5/1490 and is now referred to as SPATSIM-HDSF. Details of the design and development of SPATSIM-HDSF can be found in Clark *et al.* (2009). The further development of SPATSIM-HDSF included changes to the database structure, changes and enhancements to the main user interface, enhancements to the internal GIS functionality, development of additional time series analysis tools, and the development of an ArcGIS extension to provide further Geographic Information System (GIS) functionality. As part of the same project, the *ACRU* agrohydrological model was modified and a new model input structure and supporting tools were developed to include the *ACRU* model as one of the framework compliant models available to users.

RATIONALE

At the end of WRC project K5/1490 it was recognised that there was a need to further test and debug the new restructured SPATSIM-HDSF modelling framework, further develop the framework, further develop the modelling tools associated with the framework, and provide user training and support for the framework and associated models. The South African Department of Water Affairs (DWA) recognised the need to support SPATSIM-HDSF and associated models, and agreed to provide the funding for a project to meet these requirements.

OBJECTIVES AND AIMS

The objectives of the project were to develop capacity at DWA and within other organisations by facilitating and supporting the adoption and use of SPATSIM-HDSF by:

- Further development and stabilisation of the code into a beta version and final version.
- Developing user manuals and training materials.
- Running training workshops for users.
- Providing remote support to users of SPATSIM-HDSF for the duration of the contract.
- Incorporating, within the resources and duration of the project, requirements identified and prioritised in conjunction with users of SPATSIM-HDSF and related models.
- Improving the efficiency of use of SPATSIM-HDSF and associated models, as determined from users during workshops.
- Undertaking specific SPATSIM-HDSF related requests from DWA's Resource Directed Measures (RDM) directorate including:
    - updating the Desktop Reserve Model,
    - inclusion of Reserve studies data,
    - revision of monthly distribution curves for Reserve studies,
    - extrapolation of results from catchments where Reserve studies have been undertaken,
    - inclusion of PES/EIS table and updated tables per quaternary,
    - specifications for metadata and inclusion where available,
    - an approach for hydrological updates with existing Reserve results, and
    - visual presentation of results.

WORK COMPLETED

The work completed within the project can be broadly divided into 4 main sections:

- further development of the SPATSIM-HDSF modelling framework,
- development of the National RDM Database,
- further development of the *ACRU* model and associated tools, and
- user support and training.

SPATSIM-HDSF Modelling Framework

The main software components of the SPATSIM-HDSF modelling framework are shown in Figure 1. The SPATSIM-HDSF database data model forms the core of the modelling framework and is used to store spatial, non-spatial and temporal data for use in a hydrological modelling study. A separate SPATSIM-HDSF project and database is created for each study. The main SPATSIM-HDSF user interface is a graphical user interface (GUI) which enables users to view, add, remove, edit and analyse data stored in a SPATSIM-HDSF database. The main SPATSIM-HDSF user interface includes some internal GIS tools which are primarily intended for simple viewing of spatial data. The Data Forms library is a collection of forms, used in the main user interface and third-party software, enabling data in a SPATSIM-HDSF database to be viewed, added, removed and edited. Two Data Access libraries exist, one for .Net and one for Java, which contain standard access methods to create, populate, edit and query SPATSIM-HDSF databases. These Data Access libraries are used by the main user interface and can be used by developers of models and other third-party software to simplify access to data stored in SPATSIM-HDSF databases. Two sets of time series analysis tools, TSGRAPH and TSAnalysis can be accessed from the main user interface, and both can also be run as standalone applications. The SPATSIM-HDSF External GIS Tools, developed as an extension to the ArcGIS desktop software, enable users to utilize ArcGIS functionality to display, edit and manipulate geographical information associated with a SPATSIM-HDSF project. The SPATSIM-HDSF modelling framework has been further development within this project based on user feedback and several minor software bugs have also been resolved.

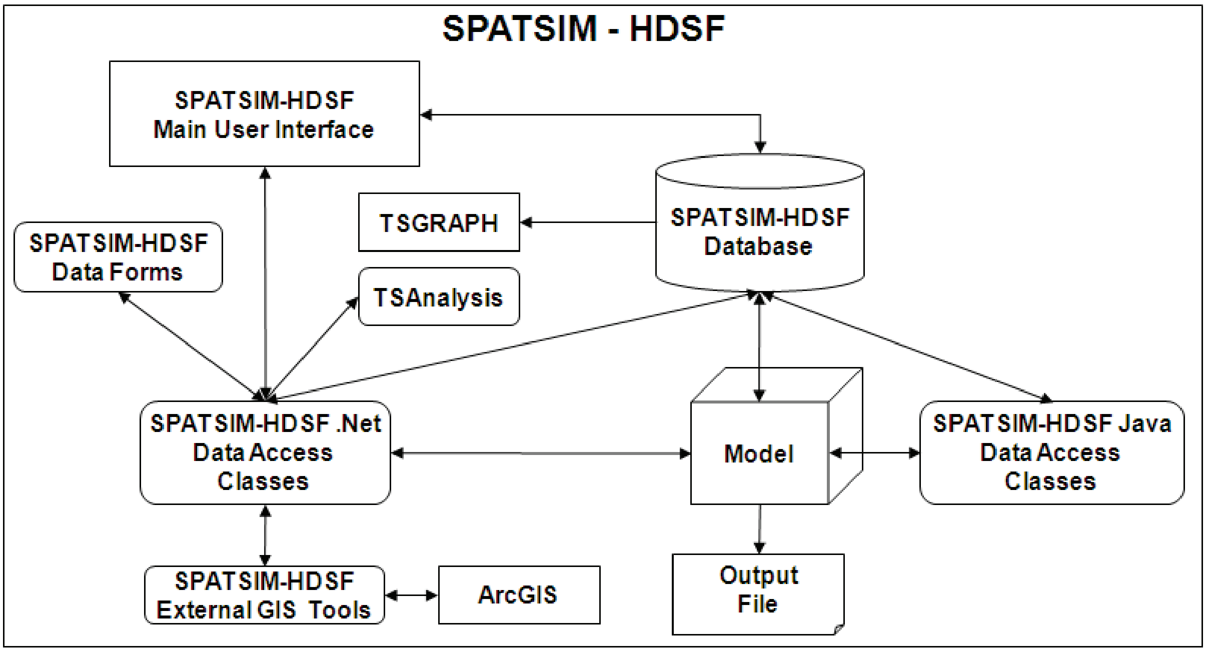

Figure 1 Main components and data flows of SPATSIM-HDSF

SPATSIM-HDSF Database Data Model

In SPATSIM-HDSF the physical entities of the hydrological system are represented by *Objects*, and sets of similar objects are known as *Features*. *Spatial Features* are represented by geographic data stored in Environmental Software Research Institute (ESRI) shape files and *Non-spatial Features* are represented by tables in the SPATSIM-HDSF database. Each *Feature* has a related set of *Attributes* stored in a SPATSIM-HDSF database. The design of the SPATSIM-HDSF database data model has remained largely unchanged since WRC Project K5/1490, except for the addition of two new fields named *ClientID* and *ChangeDate* to the *AttValMeta* table which stores metadata for individual attribute values. The purpose of these new fields is to store information required to enable changes to attribute data values to be tracked, when a user adds or edits an attribute data value in a SPATSIM-HDSF database. This will enable software tools to be developed to compare two SPATSIM-HDSF databases containing common *Features* and for a master database to be maintained based on changes made to copies of the master database.

Data Access Classes

An important part of the implementation of the SPATSIM-HDSF database data model in WRC Project K5/1490 was the development of a set of classes containing standard SPATSIM-HDSF project database access methods to create, populate, edit and query

SPATSIM-HDSF databases. These SPATSIM-HDSF project database access methods simplify database access not only in SPATSIM-HDSF, but also in the models modified to run from within the SPATSIM-HDSF framework. In this project several minor bugs in the code of the data access classes have been resolved and changes made to improve the performance of some methods. Substantial changes and additions were made to the data access classes to implement the storage of information in the *ClientID* and *ChangeDate* fields in the *AttValMeta* table.

SPATSIM-HDSF User Interface Software

The SPATSIM-HDSF user interface software has been further developed in this project to include new functionality requested by users and to include some functionality from the previous SPATSIM version that had not yet be implemented in the new version. This further development included changes to the main SPATSIM-HDSF user interface, the attribute data editing forms and the internal GIS tools. In addition several bugs in the software were resolved.

Time Series Analysis Tools

Four tools were initially developed in WRC project K5/1490 as part of the TSAnalysis library of time series analysis tools. These were *Graphs* (to enable one or more sets of time series data to be plotted for visual analysis by the user), *Statistics* (to enable a set of month-by-month and annual statistics for selected time series to be calculated, graphed and saved), *Comparative Statistics* (to enable the calculation of conservation and regression statistics between two time series) and *Frequency Analysis* (to enable monthly, partial and annual frequency analyses to be performed on a selected time series and the results displayed as a table of values or a set of graphs). As part of the current project extensive debugging and the incorporation of user feedback on these tools have been completed. In the current project, four additional tools have been developed and incorporated into the TSAnalysis library of time series analysis tools. These new tools include *Extreme Value Distributions*, *Run Length Analysis*, *High/Low Period Analysis* and *Transformations*. *Extreme Value Distributions* extracts the Annual Maximum Series (AMS) from a specified time series and fits four probability distributions (Normal, log-Normal, Gumbel and log-Pearson Type 3) to the AMS. *Run Length Analysis* computes the number of consecutive days that the values in a specified time series exceed a threshold value or are below a threshold value. *High/Low Period Analysis* computes either the highest or lowest average value for a user selected period within a time series. *Transformations* contains tools to transform a time series in a number of ways, including: accumulation, multiplication, division, addition, subtraction and via an equation.

Integrated Models

The SPATSIM-HDSF compatible models currently available to be run from within the framework include the:

- Desktop Parameter Calibration model,
- Desktop Reserve model,
- Revised Desktop Reserve model,
- Flow-Stressor Response model,
- Reserve Licensing model linked to the Desktop model,
- Real Time Reserve Management model,
- Satellite Daily Rainfall Capture process,
- Ground Water Version 3 Pitman Monthly model,
- Pitman Model Parameter Exploration tool,
- Ground Water Version 3 Uncertainty Pitman Monthly model, and
- *ACRU* agrohydrological model.

Most of the development work has involved the modification of existing models to ensure that they interface with the revised database structure of SPATSIM-HDSF. The Revised Desktop Reserve model has been recently developed as part of a separate WRC project and the current version of this model has been included within SPATSIM-HDSF.

Links to External Data Formats

The SPATSIM-HDSF modelling framework enables time series data to be imported into a SPATSIM-HDSF database using a set of data import tools provided in the main SPATSIM-HDSF user interface. A report titled "*Identification of Appropriate Links Between HDSF and Selected DWA IT/Data Systems*" was compiled as part of this project to document the existing time series data import formats currently supported by SPATASIM-HDSF and then to identify any additional time series data formats used by the DWA from which users may need to import data into SPATSIM-HDSF. The data format options previously supported by the SPATSIM-HDSF *Import T/S Data* utility include:

- *DWAF Daily Flow*,
- *Spreadsheet*,

- *HYMAS QOD*,
- *Water Quality Data*,
- *CLICOM – Daily*,
- *Continuous Text*,
- *Breakpoint*, and
- *Weather Bureau/CCWR Daily Rain*.

As part of this project new data formats were added to cater for the types of file structures that can be downloaded from the DWA website. This includes daily rainfall, streamflow and evaporation data as well as water quality data.

User Manuals and Training Materials

An important part of this project was the compilation of user manuals and training materials related to SPATSIM-HDSF. However, it is highly recommended that potential users of the SPATSIM-HDSF modelling framework first attend a course introducing the framework. The previous SPATSIM modelling framework was supported by documentation in Hypertext Markup Language (HTML) format describing the data structure, operation and associated models. In this project an updated and more comprehensive user manual was written for the new SPATSIM-HDSF version of the modelling framework. The user manual starts with some background information, development history and a general overview of the SPATSIM-HDSF modelling framework. The main components of SPATSIM-HDSF are then introduced, including the main SPATSIM-HDSF user interface, SPATSIM-HDSF database data model and the SPATSIM-HDSF external GIS tools. This is followed by a comprehensive “How To” section in which detailed instructions are provided for installation of the framework and how to use the various operations and tools within the SPATSIM-HDSF modelling framework. The models currently supported by SPATSIM-HDSF are briefly introduced with references to where further details about these models can be found. The user manual ends with a section containing information for software developers, including the design details of the SPATSIM-HDSF database data model and the data access class library. A comprehensive user manual was also created for the TSAnalysis library of time series analysis tools. This user manual starts with a brief introduction describing the purpose of this library. The general functionality common to all the tools is then explained with detailed operating instructions. Each of the eight tools is then presented in a separate chapter, where each chapter starts with an introduction to each tool followed by detailed instructions regarding the operation of the relevant tool.

The National RDM Database report (a supplementary report generated as part of this project) provides a great deal of information that is necessary for new users of SPATSIM-HDSF who will be running this specific application. It explains the structure of the database, the models that are relevant to Reserve determinations and provides guidelines on setting up and running these models. A document titled "*SPATSIM-HDSF: A Step-By-Step User Guide*" was developed as training material for the purpose of training users of the National RDM Database application of SPATSIM-HDSF, but could also be used for more general training in the use of SPATSIM-HDSF.

National RDM Database

The National RDM Database application of the previous version of SPATSIM has been transferred to the new SPATSIM-HDSF version. Part of this transfer process has included some 'cleaning up' of the database as well as the inclusion of additional data from Reserve studies undertaken by several groups of consultants. To facilitate the future management of the database a new facility has been added to SPATSIM-HDSF. This facility allows a master database to be copied to a new user who then makes some additions and changes as part of a Reserve study. The facility also allows the revisions to be 'checked-in' so that the master database is updated after a series of integrity checks to ensure that the master is not corrupted by errors or bad data.

ACRU Model

As part of WRC Project K5/1490 the *ACRU* agrohydrological model was modified and a new model input structure was developed to include the *ACRU* model as one of the framework compliant models available to users. An *ACRU* Menu Converter application was developed to enable users to convert existing *ACRU* model input files to the new model input structure with data values stored in a SPATSIM-HDSF database. A prototype *ACRU* model input configuration editor was developed to provide a graphical user interface that would enable users to populate the new *ACRU* model input files. An *ACRU* Interface form was developed to enable users to access *ACRU* related tools, and initiate *ACRU* model runs, from the SPATSIM-HDSF modelling framework. As part of the current project these supporting software tools for the *ACRU* model were debugged and further developed. The *ACRU* model itself together with its supporting software tools forms the *ACRU 4* modelling system, as shown in Figure 2.

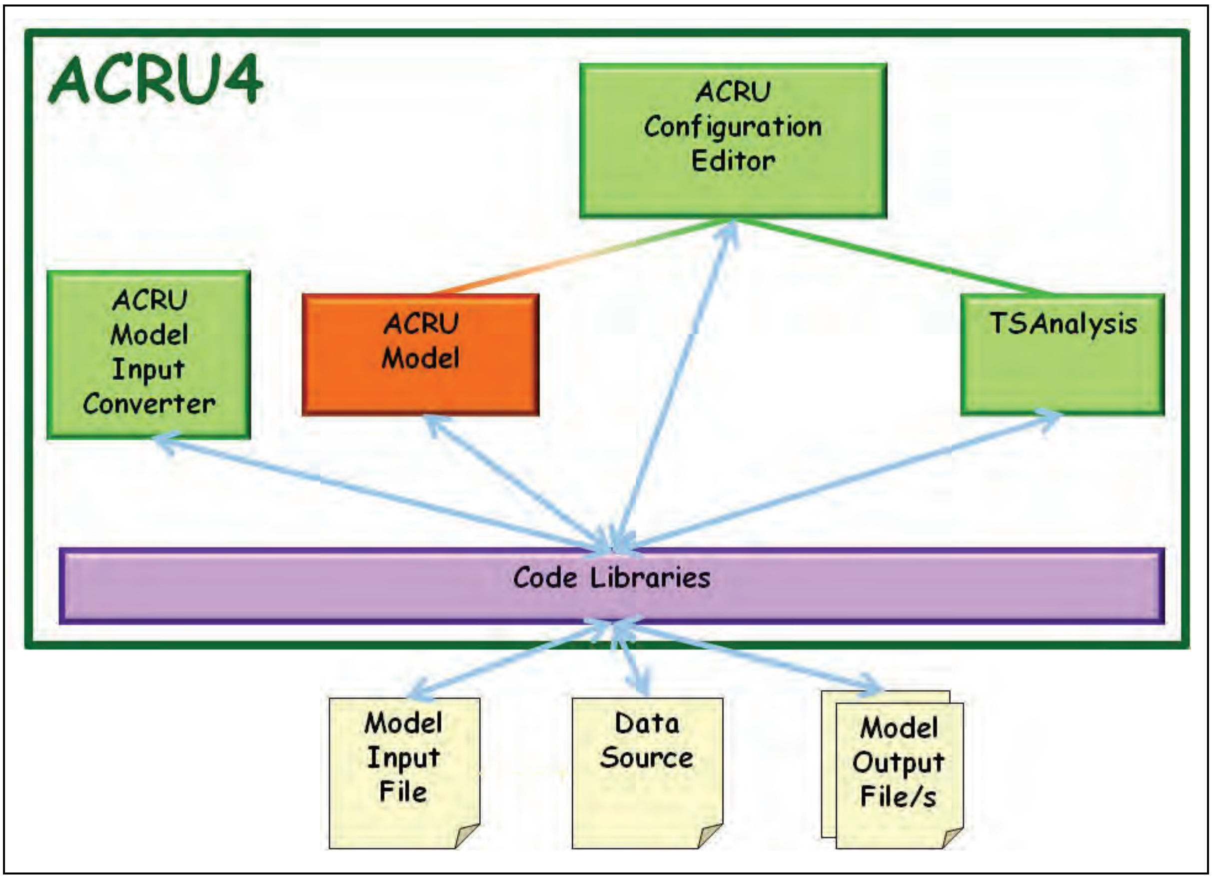

Figure 2 Simple schematic diagram of the *ACRU 4* modelling system

SPATSIM-HDSF ACRU Interface Form

The *ACRU* model is a complex model with a large number of potential variables and parameters and for this reason cannot be set up within the SPATSIM-HDSF modelling framework in the same manner as for other models included in SPATSIM-HDSF. The *ACRU* model may be setup and run from the SPATSIM-HDSF modelling framework by selecting the *ACRU Interface* form which provides access to three options: (i) to run the *ACRU Configuration Editor* application, (ii) to run an existing setup of the *ACRU* model directly from SPATSIM-HDSF, and (iii) to run the *ACRU* Menu Converter application. In this project several minor bugs in the code of the *ACRU Interface* form have been resolved and the form has been further developed.

ACRU Configuration Editor

As part of WRC Project K5/1490 a prototype model input configuration editor, known as the Configuration Editor was developed. The Configuration Editor was developed primarily for the *ACRU* model, but designed in such a way that it could be applied to other hydrological models if a suitable configuration schema file was created for each model. In this project the prototype Configuration Editor was extensively further developed to provide a flexible and extensible user interface for populating, editing and viewing model input data. The Configuration Editor has been successfully applied for the *ACRU* model. In addition to further developing user interface functionality, one of the main areas of further development was that the internal data model used within the Configuration Editor was changed to the object-oriented data model, using Extensible Markup Language (XML), developed for the *ACRU* model. This data model is based on two XML schema files: (i) a ModelData schema describing the structure of model input data and data references, and (ii) a ModelConfiguration schema describing the structure of the model specific configuration data which includes metadata about model input variables used by the Configuration Editor. Other further development included:

- The inclusion of a *Structure* tab to display the Component elements and their hierarchical parent-child tree structure.
- The inclusion of a *Relationships* tab to enable relationships between Component elements to be added and edited.
- The inclusion of a *Scenarios* tab to enable scenarios to be added and edited.
- The inclusion of an *Output Selector* tab to enable model output variables to be selected, and the format and output destination to be specified.
- The inclusion of a *Model Runs* tab to enable model runs to be added and edited.
- The complete restructuring of the code to run data and display rules and the display of the data validation results.
- The inclusion of forms enabling array and time series data to be viewed and edited.
- The inclusion of forms and code classes to enable references to data stored in external data repositories to be setup, and read data from and write data to these repositories.

ACRU Menu Converter

The *ACRU* Menu Converter application was developed in WRC Project K5/1490 to enable *ACRU* model input data files, stored in the text file format used by the *ACRU 300* series version of the model, to be converted to the XML based model input files used by the *ACRU 4* version of the model, with the option to reference data stored in a SPATSIM-HDSF database. In this project a few minor bugs in the code of the *ACRU* Menu Converter have been resolved and changes have been made to improve the performance of the application.

In addition the application has been further developed to enable conversion from model input files for the *ACRU2000* version of the model and model input files stored in CSV format by the *ACRU* Agrohydrological Modelling System (AAHMS). Functionality was also added to enable users to associate a selected ESRI shape file with a particular *ACRU* Component type, so that these can be represented as spatial features in SPATSIM-HDSF.

ACRU Model and Model Input File Structure

It was not intended within this project to make any substantial changes to the design of the *ACRU* model structure, the hydrological process modelled, or the structure of the model input data and configuration files. However, some minor modifications were made to the model and the model input data and configuration files including:

- the creation of a set of serialisation objects to read the XML model input files, which resulted in a significant improvement to the speed at which these files are read by *ACRU* model at the start of a simulation, and
- enabling users to activate or deactivate selected Component elements for specified modelling scenarios.

User Manuals and Training Materials

User manuals and training manuals for the *ACRU* model have been compiled as part of this project. However, it is highly recommended that potential users of the *ACRU* model first attend a course. A completely new user manual has been developed for the *ACRU* 4 modelling system. This user manual starts with a brief introduction to the *ACRU* 4 modelling system followed by an explanation of the key concepts of the system. The *ACRU* Configuration Editor is covered in detail, starting with an overview of the software, and followed by a comprehensive, "How To", section in which detailed instructions are provided regarding how to use the various operations and tools within the user interface. The *ACRU* Menu Converter application is briefly described. An important part of the user manual is the comprehensive set of exercises which guide the user through using the *ACRU 4* Configuration Editor to configure the *ACRU* model for a selected catchment, running the *ACRU* model, analysis of model output using the TSAnalysis library of time series analysis tools, and using the *ACRU* Menu Converter utility. A short user manual has also been created to guide users in how to use the *ACRU Interface* form which enables the *ACRU* model to be setup and run within SPATSIM-HDSF.

Typically *ACRU* training courses start with an introduction to the *ACRU* model itself and the hydrological concepts on which it is based, this is followed by an introduction to the *ACRU* 4 modelling system, after which the users are guided step-by-step through a set of practical exercises in which they use the *ACRU* 4 modelling system to setup and run the *ACRU* model for a selected catchment. A set of presentations used within the School of BEEH to introduce the *ACRU* model and the hydrological concepts on which it is based has been provided, and a presentation has been created to introduce the *ACRU* 4 modelling system. The practical exercises are part of the *ACRU 4* User Manual.

<u>User Support and Training</u>

SPATSIM-HDSF Training

During the course of the project the following workshops were held with the aim of introducing SPATSIM-HDSF to new users and updating existing SPATSIM users regarding the new SPATSIM-HDSF version of the modelling framework:

- A workshop was held on 9 March 2009 at the Water Research Commission in Pretoria. A selection of individuals involved in water resources planning, management and modelling were invited to attend the workshop.
- A workshop was held on 18 and 19 October 2010 at the DWA Roodeplaat Training Centre near Pretoria. The 28 delegates were mostly from DWA, but also included delegates from Department of Agriculture, Umgeni Water, University of Witwatersrand, University of Pretoria, and some consultants.
- A workshop was held on 11 and 12 October 2011 at the offices of BKS in Hatfield, Pretoria. The 10 delegates were mostly from the RDM section of DWA, but also included one delegate from IWMI.

ACRU Training

During the course of the project the following workshops were held with the aim of introducing the *ACRU* model to new users and updating existing *ACRU* users regarding the new *ACRU* 4 modelling system.

- A workshop was held on 23 July 2010 at the University of KwaZulu-Natal in Pietermaritzburg. The course was open to staff and postgraduate students in the School of Bioresources Engineering and Environmental Hydrology (BEEH).

- A workshop was held on 20 and 21 October 2010 at the DWA Roodeplaat Training Centre near Pretoria. The 23 delegates were from DWA, Department of Agriculture, Umgeni Water, University of Witwatersrand, University of Pretoria, University of Stellenbosch, the CSIR, and some consultants.

CONCLUSIONS

Integrated water resources management is a key requirement of the National Water Act of South Africa (Act 36 of 1998) and this has created a requirement for integrated water resources modelling. One aspect of integrated water resources modelling is the development of hydrological modelling frameworks to provide a modelling environment that facilitates the integration of models, providing a common data model and common data editing and analysis tools for use by a suite of models associated with the framework. The SPATSIM-HDSF framework is one such framework. An important part of this project has been the further development and stabilisation of the restructured SPATSIM-HDSF modelling framework developed as part of WRC Project K5/1490. An even more important outcome from this project has been the development of a comprehensive user manual for the SPATSIM-HDSF modelling framework and training of new and existing users of the framework through three workshops.

The original objective of creating a National RDM Database was to facilitate the management of Reserve studies and the results that are generated by the RDM Directorate of DWA. Many of these results are generated by different teams of consultants (service providers) and the full details of the studies have not always been returned to DWA for archiving (in many cases only the final results and the written report have been submitted to DWA). This means that it is not always a simple task to reproduce the results and make some changes if new information comes to light in the future, or if the management objectives for a specific river change in the future. The SPATSIM-HDSF project has attempted to address this issue by providing a facility that can be used by DWA to manage the data used in and generated by Reserve studies. In brief this includes a facility for consultants to ‘check-out’ the most up-to-date version of the database with a unique identification code. Upon completion of the Reserve study, the consultant will then be required to ‘check-in’ their modified version of the database. The new facility allows DWA to run various integrity checks to ensure that the master database is not corrupted by errors or mistakes made by an individual consultancy team and that the master is only updated with legitimate information appropriate to the specific Reserve study. The value of this new facility and how it will be used in practice still needs to be assessed and this can only be done once DWA start to use the system.

The incorporation of the *ACRU* agrohydrological model as one of the models available within the SPATSIM-HDSF modelling framework as part of WRC Project K5/1490, prompted a complete structuring of the structure of the model input files used to provide data to the *ACRU* model. As part of this project the structure of the *ACRU* model input files has been further developed and stabilised. In addition this project has resulted in significant further development and improvement of the tools associated with the *ACRU* model, especially the Configuration Editor, but also the *ACRU* Menu Converter and SPATSIM-HDSF *ACRU* Interface. In addition this project has resulted in the development of a comprehensive user manual for the *ACRU 4* modelling system and training of new and existing users of the model through two workshops.

In conclusion, the main objectives of the project, including further development and stabilisation of the SPATSIM-HDSF modelling framework, development of user manuals and training materials, training workshops, user support, improvement of models and development of RDM related tools have all been met. Significant improvements to the SPATSIM-HDSF modelling framework and the *ACRU 4* modelling system have been made, and both are now in use and have reached a stable stage of development. It is anticipated that new challenges in hydrological modelling will arise and that there will be new requests and suggestions from users for additional functionality.

RECOMMENDATIONS FOR FUTURE RESEARCH

A software package such as SPATSIM-HDSF should never remain static and it should be continually developing to improve efficiency and extend the range of facilities. The structure of the software has been designed to allow this to happen without affecting existing users and their applications. The long-term future of a software package such as SPATSIM-HDSF depends to a large extent on the interest of the user group, how frequently they use it and how they respond through comments, criticisms and suggestions. It will also depend on the interest of potential funders to provide the financial resources to cover some of the costs of future developments. SPATSIM-HDSF has mostly developed in a somewhat ad-hoc manner based on feedback from users regarding their requirements for new facilities, with funding for specific new functionality being provided by the users in some cases. It is recommended that SPATSIM-HDSF should evolve in the future in the same way and this can be facilitated by maintaining the capacity to modify the code at the two existing centres (IWR and BEEH) as well as expanding this capacity to other groups if this is considered appropriate. However, as the user base increases so will the need for training and user support. The questions are therefore, how will these costs be recovered, do we wish to ‘market’ the software outside South Africa, and how we will service this ‘market’ in the future? The answers to these questions cannot be provided only by the development team and therefore one of the key recommendations of this report is the establishment of a SPATSIM-HDSF user group that is made up of the development team (BEEH and IWR), DWA, the WRC and other key users within South Africa. The purpose of this group would be to monitor the use of the software, make recommendations about future developments and potential sources of funding, identify training needs and how they should be addressed and generally be responsible for the long-term sustainability of the software.

Many of the models that have currently been included as part of SPATSIM-HDSF are focussed on the analysis and simulation of water quantity, while water quality has largely been neglected. If SPATSIM-HDSF is to be considered as a system that supports the types of analyses required for integrated water resources management, it is important that water quality analysis methods are added in the future. There are many water quality models and modelling approaches available and some of these have been used within South Africa. It is therefore recommended that a future ‘user group’ investigate the possibility of including some water quality models or analysis methods.

Further improvements to the *ACRU* Configuration Editor could include:

- Functionality to enable all or specific components within an *ACRU* model input data file to be imported into other *ACRU* model input file, and to export a component to a new *ACRU* model input file.
- The manner in which projects are managed related to locations of input and output data and relative pathing.

There is a general requirement in the *ACRU* Configuration Editor for the development of data visualisation tools for both spatial and time series. Specifically, GIS related tools could include:

- Inclusion of the AAMG utility into the *ACRU 4* modelling system and modification of AAMG to write to the new *ACRU* XML model input files. AAMG is similar to the External GIS Tools in SPATSIM-HDSF but designed specifically for the setup of *ACRU* model variables through ArcGIS.

- Creation of data reader/writer and linkage classes for dBase files so that data stored in ESRI shape files can be referenced in *ACRU* model input files.
- Inclusion of GIS tools in the *ACRU* Configuration Editor for configuring Components and Relationships and for data visualisation.
- Development of tools to do statistical analyses on large sets of time series, and store the results of these analyses in a suitable format.

Recommended additions to the *ACRU* Menu Converter include:

- Functionality to specify how the subcatchments specified in an *ACRU* 3.00 or an *ACRU*2000 version model input data file are to be structured once converted. This functionality should enable users to specify whether subcatchments are to be converted as subcatchments or hydrological response units (HRUs) and how they are grouped into a hierarchy of subcatchments and catchments.
- The ability to specify reference climate files that are shared by multiple components. An example of this would be where all the HRU's within a subcatchment reference a single common reference climate.

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Mr BR Madikizela	Water Research Commission (alternate Chairman)
Ms J Jay	DWA
Mr M Lebungu	DWA
Ms MD Louw	Water for Africa
Mr K Majola	DWA
Ms N Mthethwa	DWA
Mr J Musekene	DWA
Mr E Nel	DWA
Mr SM Ngoepe	DWA
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Mr DJ Clark	School of BEEH, UKZN
Mr SLC Thornton-Dibb	School of BEEH, UKZN
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Ms JMM Stassen	Consultant
Ms E Van Niekerk	BKS

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LIST OF ABBREVIATIONS

AAHMS	*ACRU* Agrohydrological Modelling System
AAMG	Amalgamation of Agro-Hydrological Modelling Groups
AMS	Annual Maximum Series
BBM	Building Block Methodology
BEEH	School of Bioresources Engineering and Environmental Hydrology
BLOB	Binary Large Object
COM	Component Object Model
CSIR	Council for Scientific and Industrial Research
CSV	Comma Separated Value
DLL	Dynamic Link Library
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
EIS	Ecological Importance and Sensitivity
ESRI	Environmental Software Research Institute
GIS	Geographic Information System
GUI	Graphical User Interface
HDSF	Hydrological Decision Support Framework
HRU	Hydrological Response Unit
HTML	Hypertext Markup Language
IWR	Institute for Water Research
IWRM	Integrated Water Resources Management
NWA	National Water Act of South Africa, Act 36 of 1998
PES	Present Ecological State
RDBMS	Relational Database Management System
RDM	Resource Directed Measures
RDRM	Revised Desktop Reserve model
SPATSIM	Spatial and Time Series Information Modelling
SQL	Structured Query Language
UKZN	University of KwaZulu-Natal
WRC	Water Research Commission
XML	Extensible Markup Language

1 INTRODUCTION AND OBJECTIVES

The National Water Act (NWA, 1998) of South Africa (Act 36 of 1998) aims to ensure that South Africa’s water resources are managed and used in an equitable and sustainable manner for the benefit of all. The National Water Act (NWA) requires a different approach to managing the nation’s water resources and the concept of integrated water resources management (IWRM) is central to this approach (Pollard and Du Toit, 2008). IWRM requires water managers to consider hydrological, ecological, economic, political, social and institutional aspects of water resources. To implement IWRM, water managers require integrated modelling tools to provide information that can assist in making managements decisions. There are two aspects of integrated modelling that have received increasing attention in recent years: (i) the coupling of models representing different water resource domains, and (ii) the development of integrated modelling frameworks or decision support systems. These integrated modelling frameworks typically include a common data repository, common data editing tools, common spatial and temporal data visualisation and analysis tools, and a collection of framework compatible models that make use of these common tools. The SPATSIM hydrological decision support framework (HDSF) is one such modelling framework, and was the subject of further development in this project.

The Spatial and Time Series Information Modelling (SPATSIM) software was initially developed by the Institute for Water Research (IWR) at Rhodes University in South Africa and is described as an integrated hydrology and water resource information management and modelling system (Hughes, 2005; IWR, 2011). Hughes (2002) explains that SPATSIM integrates spatial and time series information in a flexible modelling framework that includes a variety of data storage, retrieval, analysis and display options suitable for the application of a range of different framework compatible models. The SPATSIM modelling framework was further developed as part of Water Research Commission (WRC) project K5/1490 and is now referred to as SPATSIM-HDSF. Details of the design and development of SPATSIM-HDSF can be found in Clark *et al.* (2009). The further development of SPATSIM-HDSF included changes to the database structure, changes and enhancements to the main user interface, enhancements to the internal GIS functionality, development of additional time series analysis tools, and the development of an ArcGIS extension to provide further Geographic Information System (GIS) functionality. As part of the same project, the *ACRU* agrohydrological model was modified and a new model input structure and supporting tools were developed to include the *ACRU* model as one of the framework compliant models available to users.

At the end of WRC project K5/1490 it was recognised that there was a need to further test and debug the new SPATSIM-HDSF modelling framework, further develop the framework, further develop the modelling tools associated with the framework, and provide user training and support for the framework and associated models. The South African Department of Water Affairs (DWA) recognised the need to support SPATSIM-HDSF and associated models and agreed to provide the funding for a project to meet these requirements. The objectives of the project were to develop capacity at DWA and within other organisations by facilitating and supporting the adoption and use of the SPATSIM-HDSF by:

- Further development and stabilisation of the code into a beta version and final version.
- Developing user manuals and training materials.
- Running training workshops for users.
- Providing remote support to users of SPATSIM-HDSF for the duration of the contract.
- Incorporating, within the resources and duration of the project, requirements identified and prioritised in conjunction with users of SPATSIM-HDSF and related models.
- Improving the efficiency of use of SPATSIM-HDSF and inbuilt models, as determined from users during workshops.
- Undertaking specific SPATSIM-HDSF related requests from DWA's Resource Directed Measures (RDM) directorate including:
  - updating the Desktop Reserve Model,
  - inclusion of Reserve studies data,
  - revision of monthly distribution curves for Reserve studies,
  - extrapolation of results from catchments where Reserve studies have been undertaken,
  - inclusion of PES/EIS table and updated tables per quaternary,
  - specifications for metadata and inclusion where available,
  - an approach for hydrological updates with existing Reserve results, and
  - visual presentation of results.

2 SPATSIM-HDSF DEVELOPMENT

SPATSIM-HDSF has been developed from the original version of SPATSIM (Hughes, 2005; Hughes and Forsyth, 2006) that was designed more than 10 years ago and has been successfully used for a number of research and practical projects for approximately the same length of time. The principles of the original design have therefore been adequately tested and this type of software has been demonstrated to be very useful. The objectives of further development (towards SPATSIM-HDSF) were largely to update the software code, ensure that the package was more reliable and robust and to improve the flexibility of the software extending its application to other areas of research and practice.

The main software components of the SPATSIM-HDSF modelling framework are shown in Figure 2-1. The SPATSIM-HDSF database data model forms the core of the modelling framework and is used to store spatial, non-spatial and temporal data for use in a hydrological modelling study. A separate SPATSIM-HDSF project and database is created for each study. The main SPATSIM-HDSF user interface is a graphical user interface (GUI) as shown in Figure 2-2 which enables users to view, add, remove, edit and analyse data stored in a SPATSIM-HDSF database. The main SPATSIM-HDSF user interface includes some internal GIS tools which are primarily intended for simple viewing of spatial data. The Data Forms library is a collection of forms, used in the main user interface and third-party software, enabling data in a SPATSIM-HDSF database to be viewed, added, removed and edited. Two Data Access libraries exist, one for .Net and one for Java, which contain standard access methods to create, populate, edit and query SPATSIM-HDSF databases. These Data Access libraries are used by the main user interface and can also be used by developers of models and other third-party software to simplify access to data stored in SPATSIM-HDSF databases. Two sets of time series analysis tools, TSGRAPH and TSAnalysis can be accessed from the main user interface, and both can also be run as standalone applications. The SPATSIM-HDSF External GIS Tools have been developed as an extension to the ArcGIS desktop software enable users to utilize ArcGIS functionality to display, edit and manipulate geographical information associated with a SPATSIM-HDSF project. The installation files for the SPATSIM-HDSF modelling framework are included in Appendix I.1.

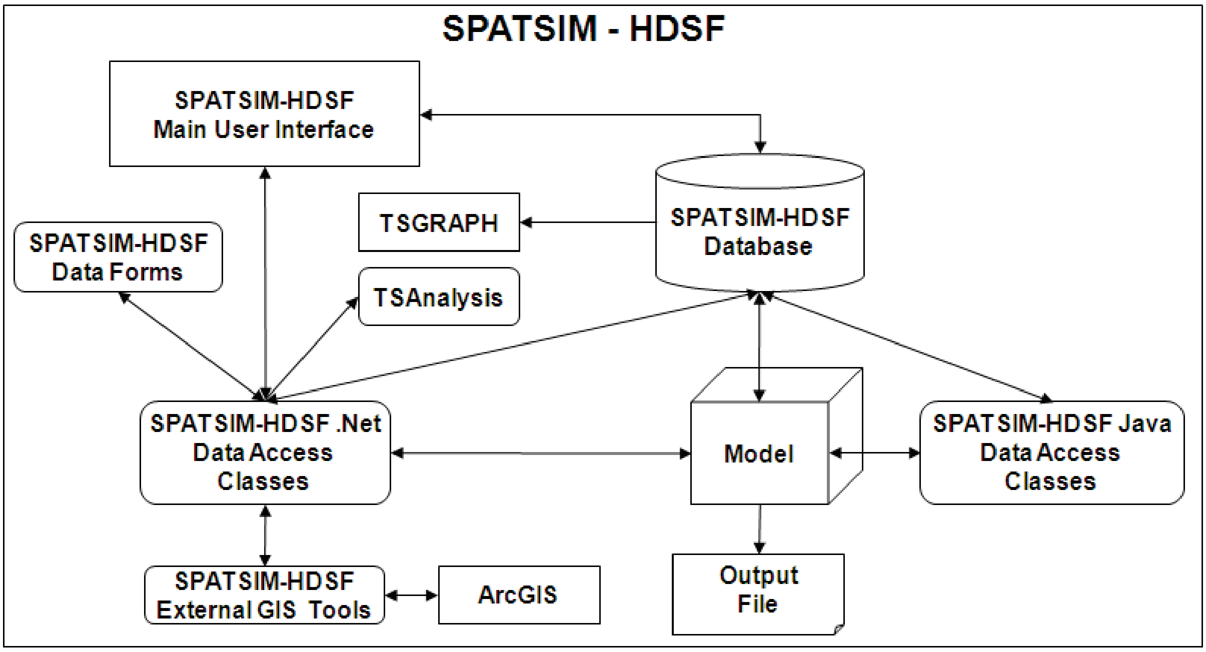

Figure 2-1 Main components and data flows of SPATSIM-HDSF

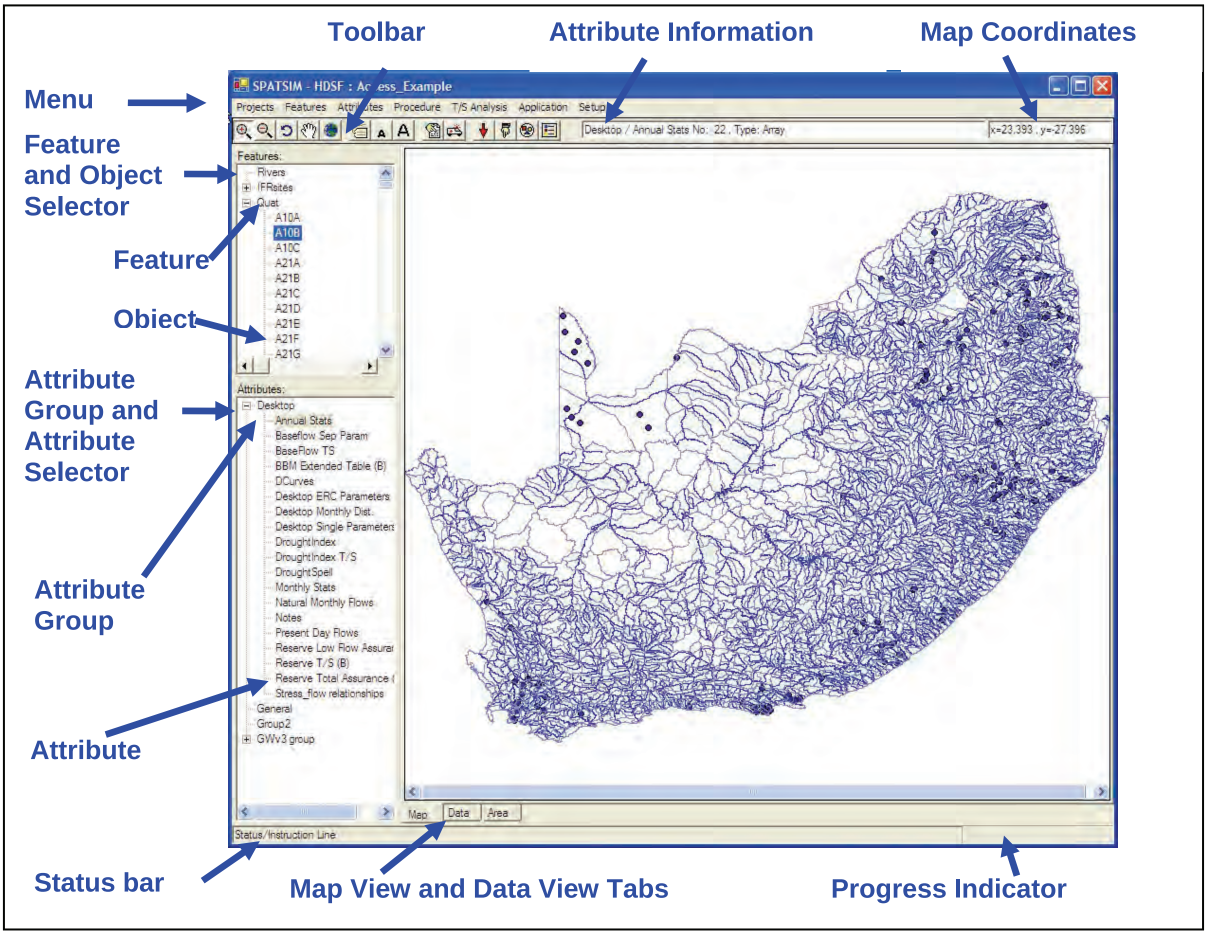

Figure 2-2 Layout of the main window in the SPATSIM-HDSF user interface

Clark *et al.* (2009) provided the following broad outline of the requirements of the main components of SPATSIM-HDSF and the purpose of each of these components:

- **Data Model:** The HDSF requires a well designed extensible data model to enable storage of both spatial and temporal data. The data model should facilitate the storage of model input and output data. It should be possible to create a separate database for each modelling project and for databases to be archived. The data model should be designed for the purpose of providing data to and receiving data from simulation models and not necessarily as a central repository for national datasets. Tools should be provided in the HDSF to import data from national databases
- **GIS Tools:** GIS will be an important tool for the setting up of model input data and information and for the analysis of model output data. The HDSF should contain a set of basic GIS tools facilitating the configuration of catchments and flow networks, and for viewing spatial model input and output data. These will be referred to as Internal GIS Tools. The HDSF should facilitate exchange of data with commercial GIS systems and possibly provide HDSF specific tools to be used within these commercial GIS systems. These will be referred to as External GIS Tools. The HDSF should be based on the most widely used GIS data formats.
- **Model Input:** The HDSF should have a user friendly GUI allowing model input data to be entered and reviewed with facility to do range and logic checking of data entered. Ideally the HDSF should provide an extensible generic GUI suitable for all models. However, provision should be made for model specific GUIs to be used as these often contain complex data checks.
- **Data Analysis:** The HDSF should include a comprehensive and easy to use set of tools for analysis and display of model output. These tools should include the graphing and comparison of time series data and associated statistical analyses.
- **Models:** The HDSF should allow new models to be added in as simple a manner as possible, although it is recognised that the addition of a new model would only be done by the developers of the HDSF, or suitably qualified experts, and not by every user of the HDSF. It should be possible to add legacy models to the HDSF and the addition of these legacy models should require the minimum of code changes. The links between models and other components of the HDSF such as the GUI, GIS tools and database should be as extensible as possible to allow for changes to models. The HDSF should include facilities for the linking of models in series and parallel.
- **General:** The HDSF should include a system of managing modelling projects and different scenarios within a project, and the archiving of projects. The HDSF is intended to run on the Windows operating platform.
- **Help:** The HDSF should include a system of help files explaining the use of the HDSF and each of the models that may be run from the HDSF.

At the end of WRC project K5/1490 a working version of the SPATSIM-HDSF modelling framework that met most of these requirements existed, but had not been extensively tested or used, and the need to provide training for both existing SPATSIM users and new users had been recognised. In addition several areas for further development of the SPATSIM HDSF modelling framework had been identified. These areas of further development and general stabilisation of the code were addressed in the project and are described in more detail in this chapter. An updated installation procedure was also developed to automatically install all components of the SPATSIM-HDSF modelling framework software including 3rd party libraries.

2.1 SPATSIM-HDSF Database Data Model

In SPATSIM-HDSF the physical entities of the hydrological system are represented by *Objects*, and sets of similar objects are known as *Features*. *Spatial Features* are represented by geographic data stored in Environmental Software Research Institute (ESRI) shape files and *Non-spatial Features* are represented by tables in a SPATSIM-HDSF database. Each *Feature* has a related set of *Attributes* stored in a SPATSIM-HDSF database. *Attribute* values are stored in a set of *Attribute* value tables based on their *Attribute* data type. Entity relationship diagrams of the SPATSIM-HDSF database data model are shown in Figure 2-3 and Figure 2-4. Only some of the relationships between tables have been shown in Figure 2-3 in order to simplify the diagram. Descriptions, data types and other properties of the fields in each table in the SPATSIM-HDSF database data model are documented in the SPATSIM-HDSF User Manual included in Appendix A [also in Appendix I.2].

The SPATSIM-HDSF database data model forms the core of the modelling framework and was designed to meet the following requirements:

- Be extensible – adding new models and model variables must not require changes to the data model.
- Be generic – it must be suitable for application to a wide range of hydrology related models.
- Be object-oriented – it must enable storage of data in a manner suited to application with object-oriented models.
- Enable spatial and non-spatial components of the hydrological system to be represented.
- Enable storage of static and time series data.
- Enable linking of model variables to Attributes in multiple Features representing different components of the hydrological system.
- Store global model variables not related to components of the hydrological system.
- Represent relationships between components of hydrological system.
- Enable easy running of different scenarios, while avoiding unnecessary repetition of data.
- Enable storage of metadata about datasets and values.
- Store units of measure for all relevant data types.
- Include the feasibility of linking to the ArcGIS geodatabase data model.

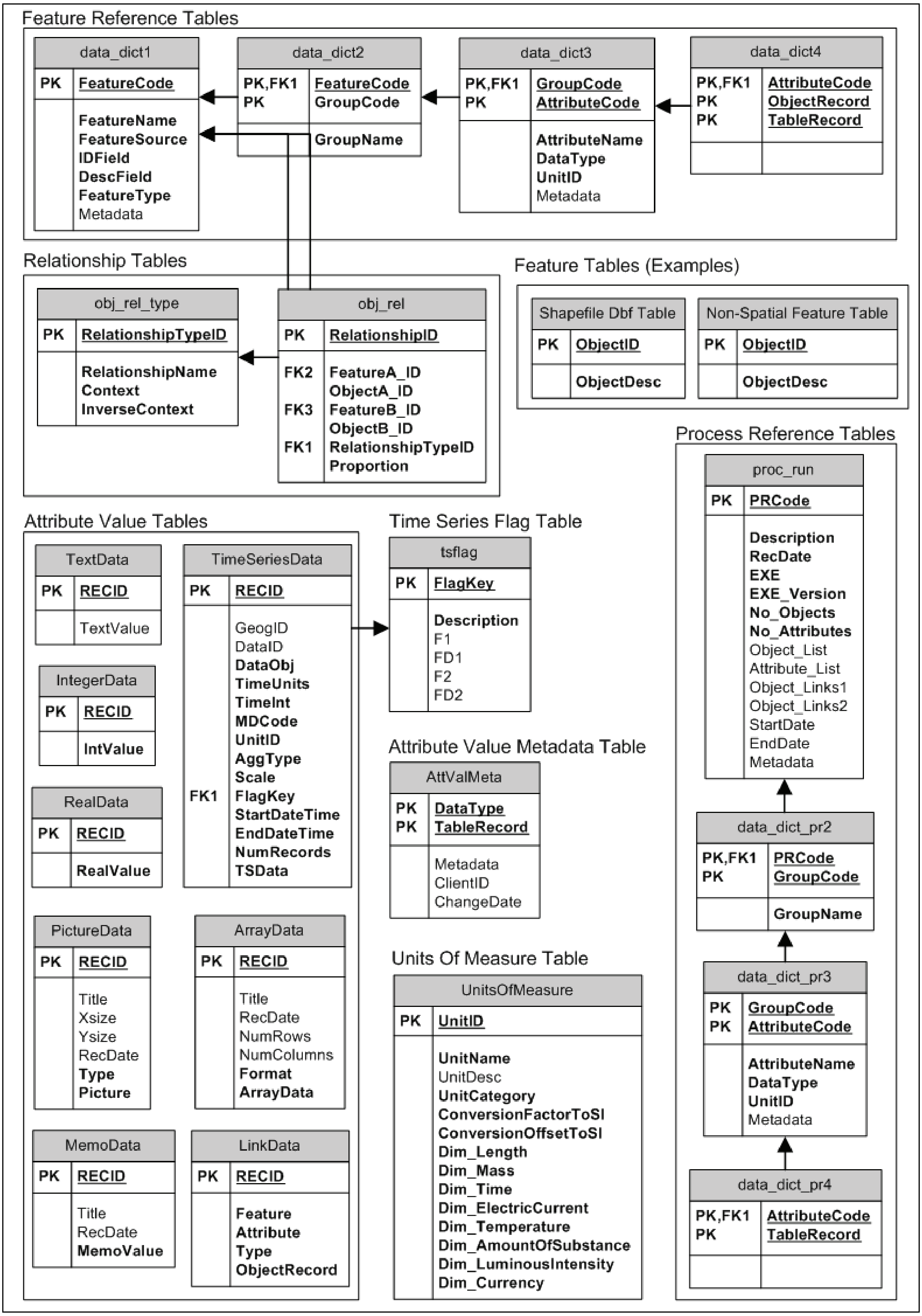

Figure 2-3 Main entity relationship diagram of the SPATSIM-HDSF database data model

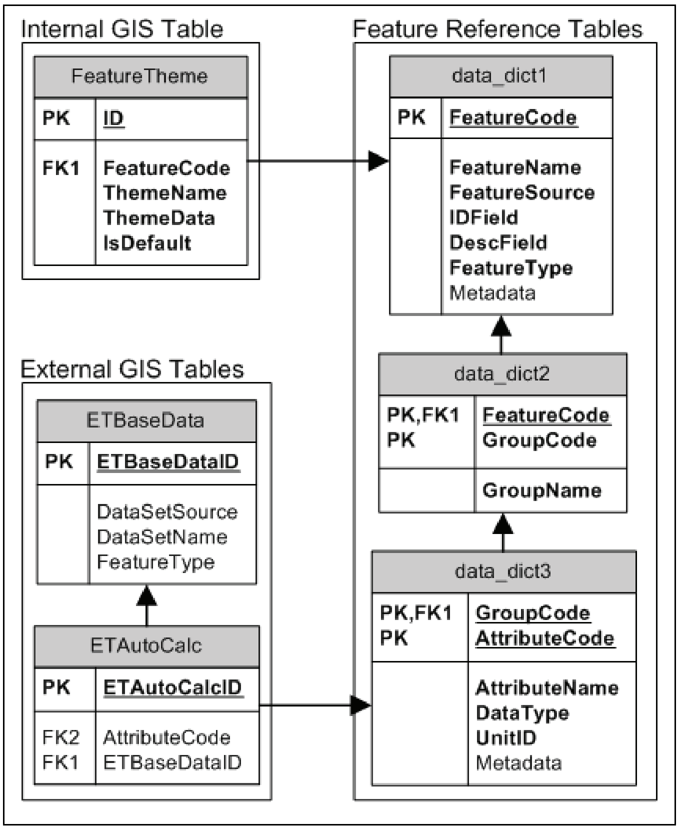

Figure 2-4 Entity relationship diagram of the GIS related tables in the SPATSIM-HDSF database data model

The design of the SPATSIM-HDSF database data model has remained largely unchanged since WRC Project K5/1490, as described in Clark *et al.* (2009), except for the addition of two new fields named *ClientID* and *ChangeDate* to the *AttValMeta* table. The purpose of the new *ClientID* and *ChangeDate* fields is to store information to enable changes to attribute data values to be tracked. When a user adds or edits an attribute data value in a SPATSIM-HDSF database then the ClientID for that user and the date that the change was made will be automatically stored if the SPATSIM-HDSF Data Access library is used. This will enable software tools to be developed to compare two SPATSIM-HDSF databases containing common *Features* and for a master database to be maintained based on changes made to copies of the master database.

2.2 Data Access Libraries

An important part of the implementation of the SPATSIM-HDSF database data model in WRC Project K5/1490 was the development of the Data Access library of classes containing standard SPATSIM-HDSF project database access methods to create, populate, edit and query SPATSIM-HDSF databases. These SPATSIM-HDSF database access methods simplify database access not only in SPATSIM-HDSF, but also in the models modified to run from within the SPATSIM-HDSF framework. The main classes are named *DataAccess*, *Database*, *IniInfo*, *TSInfo* and *ArrayInfo*. A .Net version of these classes is packaged as a library which can be used in code written in any .Net programming language. This library also contains a similar set of Component Object Model (COM) accessible classes developed for use in legacy models written in a variety of programming languages that would not be able to utilise these .Net compliant classes. Further, a Java version of the data access classes was created to simplify use of these classes in Java code and provide better run-time performance. As far as possible these database access classes were based on standard Structured Query Language (SQL) queries to facilitate possible use with a selection of relational database management systems (RDBMSs). These classes are described in more detail in Clark *et al.* (2009) and in the SPATSIM-HDSF User Manual included in Appendix A [also in Appendix I.2].

In this project several minor bugs in the code of the data access classes have been resolved and changes made to improve the performance of some methods. Substantial changes and additions were made to the Data Access classes to implement the storage of information in the *ClientID* and *ChangeDate* fields in the *AttValMeta* table. A summary of the changes made to the SPATSIM-HDSF Data Access classes is shown in Table 2-1.

Table 2-1 Summary of changes made to the Data Access classes

Class Name	**Description**
DataAccess	Modified the *isDBTable* methods as these were too slow when used on tables containing large amounts of data.
Database	Added the *getFeatureObjects_AssignedData* method to find objects that have data associated with them for a *Spatial Feature* or a *Non-Spatial Feature*.
Database	Added the *getFeatureObjects_Binary* method to get all objects belonging to a *Spatial Feature* or a *Non-Spatial Feature.*
DataAccess	Added the *clientID* instance variable.
DataAccess *Database*	Added the *getClientID* and *setClientID* methods.
DataAccess *Database*	Added the *openWithClient* methods.
DataAccess *Database*	Modified the *createAttValMetaTable* method to include new *ClientID* and *ChangeDate* fields.

Class Name	Description
DataAccess Database	Removed the *getAttValueMetadata* and *getProcAttValueMetadata* methods.
DataAccess	Added the *getAttValMetaQuery*, *getAttValueMetadataQuery* and *getProcAttValueMetadataQuery* methods.
Database	Added the *getAttValMeta*, *getAttValueMetadata* and *getProcAttValueMetadata* methods.
DataAccess Database	Modified the existing *updateAttValMetaRecord* method to automatically set *ClientID* and *ChangeDate* when metadata is updated, and added a new *updateAttValMetaRecord* method to update the *ClientID* and *ChangeDate*.
DataAccess Database	Modified the existing *updateAttValueMetadata* method to automatically set *ClientID* and *ChangeDate* when metadata is updated, and added a new *updateAttValueMetadata* method to update the *ClientID* and *ChangeDate*.
DataAccess Database	Modified the existing *updateProcAttValueMetadata* method to automatically set *ClientID* and *ChangeDate* when metadata is updated, and added a new *updateProcAttValueMetadata* method to update the *ClientID* and *ChangeDate*.
DataAccess Database	Modified the existing *insertAttValMetaRecord* method to automatically set *ClientID* and *ChangeDate* when metadata is inserted, and added a new *insertAttValMetaRecord* method to set the *ClientID* and *ChangeDate*.
DataAccess Database	Modified the existing *insertAttValueMetadata* method to automatically set *ClientID* and *ChangeDate* when metadata is inserted, and added a new *insertAttValueMetadata* method to set the *ClientID* and *ChangeDate*.
DataAccess Database	Modified the existing *insertProcAttValueMetadata* method to automatically set *ClientID* and *ChangeDate* when metadata is inserted, and added a new *insertProcAttValueMetadata* method to set the *ClientID* and *ChangeDate*.
DataAccess	Modified the relevant *insertTextAttValue*, *insertIntegerAttValue*, *insertRealAttValue*, *insertTSAttValue*, *insertPictureAttValue*, *insertArrayAttValue*, *insertMemoAttValue* and *insertLinkAttValue* methods by including code to call the *updateAttValMetaRecord* method to record that the attribute value has been changed.
DataAccess	Modified the relevant *updateTextAttValue*, *updateIntegerAttValue*, *updateRealAttValue*, *updateTSAttValue*, *updatePictureAttValue*, *updateArrayAttValue*, *updateMemoAttValue* and *updateLinkAttValue* methods by including code to call the *updateAttValMetaRecord* method to record that the attribute value has been changed.
DataAccess	Modified the relevant *insertAttValMetaRecord* and *insertProcAttValMetaRecord* methods to update existing records (previously an exception was thrown if the record already existed).

Class Name	Description
DataAccess Database	Added two new *insertAttValMetaRecords* methods to insert and/or update a batch of *AttValMeta* table records.
DataAccess	Modified the *insertTextAttValues*, *insertIntegerAttValues*, *insertRealAttValues*, *insertTSAttValues*, *insertPictureAttValues*, *insertArrayAttValues*, *insertMemoAttValues* and *insertLinkAttValues* methods by including code to call the *updateAttValMetaRecords* method to record that attribute values have been changed.
DataAccess	Modified the *updateStringField*, *updateInt16Field*, *updateInt32Field*, *updateSingleField*, *updateDoubleField*, *updateDateField*, *updateTimeField*, *updateDateTimeField*, *updateMemoField* and *updateBLOBField* methods by including code to call the *updateAttValMetaRecord* method to record that the attribute value has been changed.
IniInfo	Added the *client_ID* instance variable and associated *getClientID* and *setClientID* methods.
TSInfo	Made changes to the *insertRecord* method to correctly add a record to the end of a time series for *DataObj*=0 and *DataObj*=1.
ArrayInfo	Replaced all use of the *FileExists* method with *FileInfo* method when checking if a file exists.

2.3 SPATSIM-HDSF User Interface Software

The SPATSIM-HDSF user interface software has been further developed in this project to include new functionality requested by users and to include some functionality from the previous SPATSIM version that had not yet been implemented in the new version. In addition several bugs in the software were resolved.

Main User Interface

The main SPATSIM-HDSF user interface shown in Figure 2-2 consists of a menu bar and tool bar at the top of the form, a navigation panel on the left-hand side of the form and a display panel on the right-hand side of the form. In the navigation panel the Feature Selector at the top is a tree-view including a list of all the objects within a feature. Selecting one of the objects belonging to a spatial feature, highlights the object on the map in the display panel. In the navigation panel the Attribute Selector at the bottom is a tree-view displaying attribute groups and the attributes contained within them. The tabbed page labelled *Maps* displays maps for spatial features, and the tabbed page labelled *Data* displays a data grid showing attribute values for a selected spatial or non-spatial feature and attribute group. The menu bar contains commands and tools enabling project management, addition, editing and removal of features and attributes, importing data, access to time series and other tools, and running models. The tool bar mostly contains tools used to adjust the display of maps and selection of feature objects on maps. Further details regarding the main SPATSIM-HDSF user interface can be found in Clark *et al.* (2009), and the SPATSIM-HDSF User Manual included in Appendix A [also in Appendix I.2].

In this project several minor bugs in the code of the main SPATSIM-HDSF user interface have been resolved and changes made to improve the functionality. A summary of the changes made to the main SPATSIM-HDSF user interface is shown in Table 2-2.

Table 2-2 Summary of changes made to the main SPATSIM-HDSF user interface

Description
Added code to display non-spatial features in Feature Selector.
Added code to enable selection of multiple objects in the Feature Selector.
Added code to open the *Compare Arrays* form from the *Attributes* menu.
Added code to prevent exceptions arising when select labelling and attribute operations in a new project with no features.
Also added code to prevent the *Data* tab from being displayed in a new project with no features or attributes.
Added code to prevent map operations such as displaying labels if a non-spatial feature is selected.
Added code to prevent editing of an empty grid in the *Data* tab.
Added checks to see whether an attribute is selected when the *Show Attribute* button is clicked.
Added code to enable addition of non-spatial features to a SPATSIM-HDSF project, and bulk import of data to a non-spatial feature from comma separated value (CSV) files.
Added functionality to export time series and memo data to text files for easy import into another SPATSIM-HDSF project. Following this process the user can select which data should be transferred and thus ensure that the new database does not contain redundant data.
Added functionality to the *Project Selection* form to enable whole SPATSIM-HDSF projects to be imported and exported. An existing project can be exported to a folder which can then be sent to another user, who can then import the project into SPATSIM-HDSF on their computer. Further details about this new functionality can be found in the SPATSIM-HDSF User Manual included in Appendix A [also in Appendix I.2].
Completed conversion of all the currently used procedures. The list of procedures available in the *Procedures* menu item now include: *T/S Summary*, *Drought Indices*, *Sub Quat MAR*, *Transform T/S* and *Point to Area*.

Description
Completed conversion of all the currently used *Features* menu utilities, which now includes: *Spatial Relationships*, *Google Earth Image*, *Get Map*, *Point Features* and *Output Map*.
Modified the *Manage Groups/Attribute* form in SPATSIM-HDSF to make it easier to use.
Modified *Data* tab to enable resizing of tabbed-page if the main form is resized.
Modified code to return correct *FeatureCode* when adding a new feature.
On *Data* tab fixed an error that occurred when editing data after a search.
Corrected an error message to users that occurs when an incorrect attribute operation is selected.
Added code to enable a 'Master' version of an application to be distributed to other users (with a client identification) and then checked back in to update the 'Master' version when changes have been made. This code has been added to enable DWA to manage the RDM application which involves many consultants who are expected to add new information about Reserve determinations.

Attribute Data Editing Forms

The SPATSIM-HDSF user interface includes a set of attribute data editing forms enabling framework users to add or edit attribute data values for both feature and process attributes. These forms, described in Clark *et al.* (2009), consist of a set of modal forms, one form for each of the attribute data types, namely: Text, Integer, Real, Time Series, Picture, Array, Memo and Link. The feature and process attribute data editing forms have been developed in the Delphi for .Net programming language and are packaged as a Dynamic Link Library (DLL) named *SPATSIM_DataForms.dll* and are thus available to be used in any code written in a .Net programming language, enabling them to be used in third-party software tools. Further details regarding the use of the attribute data editing forms can be found in the SPATSIM-HDSF User Manual included in Appendix A [also in Appendix I.2].

In this project several minor bugs in the code of the attribute data editing forms have been resolved and changes made to improve the functionality of these tools. A summary of the changes made to the SPATSIM-HDSF attribute data editing forms is shown in Table 2-4.

Table 2-3 Summary of changes made to the SPATSIM-HDSF attribute data editing forms

Description
Added code to pass *CoverPath* as a parameter from SPATSIM-HDSF, which is needed if cannot find the relevant shape file from the file path specified in the database.
Added code to deal with situations where no objects are passed to the *CompareArray* form or none of the objects in the list passed to the form have attribute data values assigned to them.
Added code to read time series data stored in text and CSV files and import the time series data into a Time Series type attribute in a SPATSIM-HDSF database. The text and CSV files are required to be in a specified format.
Modified code to prevent forms being hidden behind the main user interface form.
Modified code to improve speed of display of Time Series type attribute data.
Modified code in the *Time Series Data* form to ensure correct enabling and disabling of the DataObject and TimeUnits controls for existing Time Series type attributes.
Modified code in the *Time Series Data* form so that after viewing an existing Time Series type attribute, all controls will be disabled if the *Attribute Group* is changed, till an *Attribute* has been selected.
Modified code so that after viewing an existing Time Series type attribute, if a new Time Series type attribute with no data is viewed, the unit of measure from the previous Time Series type attribute is cleared.
Modified code so that when viewing an existing Time Series type attribute, the *Flag* control is correctly enabled and disabled depending on the *FlagKey* option selected.
Modified code related to importing Array type attribute data from text files.
Modified code related to the *CompareArray* form to prevent problems with duplicate objects being passed to the *CompareArray* form.
Modified the *CompareArray* form to correctly enable the Close button.

Internal GIS Tools

The SPATSIM-HDSF user interface software contains a set of built-in GIS tools providing a spatial view of model input and output parameters. These internal GIS tools are intended to provide a basic set of GIS tools enabling users to setup and run hydrological models without requiring expensive commercial GIS software and are described in more detail in Clark *et al.* (2009). The internal GIS tools in SPATSIM-HDSF have been developed using ESRI MapObjects GIS software development components, and use ESRI shape files as the storage format for geographical data. Further details regarding the use of the internal GIS tools can be found in the SPATSIM-HDSF User Manual included in Appendix A [also in Appendix I.2].

The internal GIS functionality currently provided in SPATSIM-HDSF includes the following:

- Display Spatial Features in the *Map* tabbed page.
- Set up themes and display these in a legend.
- Zoom-in, zoom-out, zoom-to-previous-extent, pan and zoom-to-full-extent tools.
- Show, hide and resize spatial feature labels.
- Rendering of a Spatial Feature as a theme using Attribute values.
- Selection of Spatial Feature Objects on the map for use in other SPATSIM-HDSF tools and models.

In this project several minor bugs in the code of the internal GIS tools have been resolved and changes made to improve the functionality of these tools. A summary of the changes made to the SPATSIM-HDSF internal GIS tools is shown in Table 2-4.

Table 2-4 Summary of changes made to the SPATSIM-HDSF internal GIS tools

Description
Added functionality to the *Edit Theme* form to read Array type attribute row and column names.
Added functionality to the *Edit Theme* form to determine maximum and minimum data values for an attribute and use these as defaults in the *ClassBreak* theme *Type* option.
Added code to prevent display of the *Edit Theme* command in the Feature Selector when a Non-spatial Feature is selected.
Modified code to cater for coverages with a large dataset of objects. For coverages with spatial object sets larger than a specified number (2500), the nodes are not displayed within the Feature and Object Selector. If a user would still like to display the spatial objects within the Feature and Object Selector there is an option under the pop-up menu to enable this.
Modified the *Edit Theme* form to ensure correct values are read from Array type attributes.
Modified the *Edit Theme* form to ensure corrected display of *Source Attribute* list when different *Source Group* is selected.

2.4 Time Series Analysis Tools

One of the requirements of the HDSF was that it should include a set of tools for analysis and display of model input and output time series data. The SPATSIM-HDSF modelling framework includes two sets of time series analysis tools: (i) the TSGraph tools, previously known as TSOFT, and (ii) the TSAnalysis tools library, initially developed in WRC project K5/1490 and further developed in this project.

TSGraph Tools

The previous version of SPATSIM contained a comprehensive set of tools for displaying and analysing time series through the TSOFT utility. The basis of the previous approach was to load specific time series data to a TSOFT 'profile' which could then be selected for use in the TSOFT utility and individual time series contained within the profile selected for plotting and analysis. The TSOFT utility enables many different time series to be selected and displayed together on two sets of graph axes. The time series could also be converted in certain cases, an example being daily streamflow data aggregated to monthly volumes (to enable daily observed data to be compared with monthly simulated data). The TSOFT utility allows any of the time series to be summarised or analysed, such as monthly distributions and flow duration curves. Two time series can also be statistically and graphically compared with each other (using scatter plots), a utility commonly used in the calibration of a hydrological model against observed data.

The changes that were made during the conversion of TSOFT to SPATSIM-HDSF concentrated on improving the efficiency and flexibility of the approach rather than adding or removing any of the analysis methods (which were considered to be comprehensive enough for most users' requirements). The first improvement involved a different approach to referencing the time series attribute information contained within a profile. The SPATSIM-HDSF approach uses a table that is part of the database rather than the binary file approach that was used previously. From a user point of view this is a rather superfluous change, but does make the access to the time series information more efficient. The second major change was the addition of a facility to load multiple time series to the graphs at one time. This was not available within the earlier version and made it quite time consuming when the user wished to look at a number of superimposed time series (they had to be added one at a time). A third improvement in efficiency enables the user to select the default options for displaying time series (i.e. the full time series rather than a selected part of it and displaying the data using the original data time step – i.e. no aggregation of data). Some other minor changes were made to the options available for displaying the data and background with different colours. Although trivial, these changes were made because different colours have been found to be appropriate for different displays (i.e. differences between a normal computer screen display and a display through a data projector).

TSAnalysis Tools Library

Four tools were initially developed in WRC project K5/1490 as part of the TSAnalysis library of time series analysis tools. These were *Graphs* (to enable one or more sets of time series data to be plotted for visual analysis by the user), *Statistics* (to enable a set of month-by-month and annual statistics for selected time series to be calculated, graphed and saved), *Comparative Statistics* (to enable the calculation of conservation and regression statistics between two time series) and *Frequency Analysis* (to enable monthly, partial and annual frequency analyses to be performed on a selected time series and the results displayed as a table of values or a set of graphs). Details of the tools included in the TSAnalysis library can be found in the TSAnalysis User Manual included in Appendix C [also in Appendix I.2]. As part of the current project, extensive debugging and the incorporation of user feedback on these tools have been completed. A summary of the changes made to these tools is shown in Table 2-5.

Table 2-5 Summary of changes made to the tools in the TSAnalysis library

Tool	**Description**
General	For all graphs added options to print and export as an image.
	Added code to enable time series data to be exported to text and CSV files.
	Modified naming of analysis template files and saving files to project directory: • Added a dialog box for users to specify a name for an analysis when saving. • Modified analysis template file and added code to enable saving of analysis name.
	Added code to set default maximum and minimum thresholds.
	Changed design of analysis template file to handle analysis data stored in different orders.
	Added additional constructors to include the *CoverPath* parameter and implemented these in the main SPATSIM-HDSF user interface.
	Added ToolTips to display full data source path.
	Modified code to automatically retrieve selected data and conduct analysis using parameters passed from SPATSIM-HDSF when a time series is selected for analysis in the SPATSIM-HDSF user interface using the map, the object and attribute selectors or from the *Time Series Data* form.
	Upgraded Steema software used in TSAnalysis library for plotting graphs.
Graphs	Added code to prevent duplicate short names for series when adding a series to a graph
	Modified code to correctly store and read *Scale* in the analysis template file.

Tool	Description
Statistics	Created form to enable selection of multiple objects.
	Modified code to read correct *MDCode* value when reading data from an analysis template file.
	Added code so that data displayed in the data grid per month is in order starting with the hydrological month selected.
Comparative Statistics	On the *Analysis* form corrected the y-axis and x-axis labels.
Frequency Analysis	Created form to enable selection of multiple objects.
	Added code so that data displayed in the data grid per month is in order starting with the hydrological month selected.
	Added in ability to perform a frequency analysis on multiple objects.
	Added code to enable editing of percentiles used in a frequency analysis.

Four additional tools have been developed and incorporated into the TSAnalysis library of time series analysis tools. These new tools include *Extreme Value Distributions*, *Run Length Analysis*, *High/Low Period Analysis* and *Transformations*. *Extreme Value Distributions* extracts the Annual Maximum Series (AMS) from a specified time series and fits four probability distributions (Normal, log-Normal, Gumbel and log-Pearson Type 3) to the AMS. The results are displayed in a tabular format and plotted on a graph. *Run Length Analysis* computes the number of consecutive days that the values in a specified time series exceed a threshold value or are below a threshold value. Up to 6 threshold values can be used and the results of the analyses are plotted on a graph. *High/Low Period Analysis* computes either the highest or lowest average value for a user selected period within a time series. The value is displayed together with the start and end date for that period within the time series. *Transformations* contains an *Equation Transformation* section and a *General Transformation section*. The *Equation Transformation* section transforms a time series dataset according to an equation. There are two equations, $y = Ax^2 + Bx + C$, and $y = Ax^B + C$, where y is the transformed value, x are the values from the time series dataset, and the values of A, B and C are coefficients set by the user. The *General Transformation* section contains the following transformations:

- *Accumulate TS*: creates an accumulated time series (TS) from the original time series data set.
- *Accumulate X TS*: creates an accumulated time series according to a period length.
- *TS * Y*: creates a transformed time series where the values from the original time series data are multiplied by Y.

- *TS / Y*: creates a transformed time series where the values from the original time series data set are divided by Y.
- *TS1 + TS2*: creates a transformed time series which is the addition of two time series data sets, TS1 and TS2.
- *TS1 – TS2*: creates a transformed time series which is the difference of two time series data sets, TS1 and TS2.
- *TS1 – Median TS2*: creates a transformed time series which is the difference between a time series data set, TS1 and the median of time series data set, TS2.
- *TS1 – Mean TS2*: creates a transformed time series which is the difference between a time series data set, TS1 and the mean of time series data set, TS2.

2.5 Integrated Models

The SPATSIM-HDSF compatible models currently available to be run from within the framework include the:

- Desktop Parameter Calibration model,
- Desktop Reserve model,
- Revised Desktop Reserve model,
- Flow-Stressor Response model,
- Reserve Licensing model linked to the Desktop Reserve model,
- Real Time Reserve Management model,
- Satellite Daily Rainfall Capture process,
- Ground Water Version 3 Pitman Monthly model,
- Pitman Model Parameter Exploration tool,
- Ground Water Version 3 Uncertainty Pitman Monthly model, and
- ACRU agrohydrological model.

A brief introduction to these models and references to further documentation can be found in in the SPATSIM-HDSF User Manual included in Appendix A [also in Appendix I.2]. The National RDM Database User Manual (included in Appendix D [also in Appendix I.2]) contains more details about most of the models with the exception of the Revised Desktop Reserve model and the *ACRU* model. Brief descriptions of the models are provided below, while in many cases additional documentation can be found in the publications provided by the references. In most cases (with the exception of the *ACRU* model interface) the development work that was undertaken as part of this project was mainly to re-structure the

data input and output components of the models to be consistent with the new database structure of SPATSIM-HDSF compared with the structure of the older SPATSIM software.
The Desktop Parameter Calibration model was developed to allow summary information from a large number of Reserve studies to be integrated and compared with the results that would be generated by using the default regional parameters of the Desktop Reserve model. Various options are available to adjust the default parameters and to assess whether or not they should be changed for different regions of the country.

The Desktop Reserve model (Hughes and Hannart, 2003) is the original model that has been used by DWA to determine rapid, but low-confidence, estimates of the Reserve for a number of years. It is based on the Building Block Methodology (BBM) approach to setting Reserves.

The Flow-Stressor Response model (Hughes and Louw, 2010) is used to process the ecological stress information generated by the ecological specialists at a Reserve workshop and integrate it with various hydrological scenarios (natural, present day and Reserves for different ecological categories). It is used together with the Desktop Reserve model to establish the volumes and assurance rules for a Reserve.

The Reserve Licensing model (Hughes, 2006) uses the outputs from the Desktop Reserve model (the original or revised version) together with information on natural hydrology and both present day and future water use to assess the extent to which the Reserve can be met under different development scenarios. It is designed for small to moderate sized catchments that do not have large reservoirs with complex operating rules and can be used to assess the viability of future applications for water use licences.

The Satellite Daily Rainfall Capture process and Real Time Reserve Management model (Hughes and Mallory, 2008) are designed for managing releases from reservoirs or water user curtailments in near real time (time scales of 10 days to a month). The basis of these models is the use of satellite rainfall data to update the simulations of natural stream flow (using a pre-calibrated version of the Pitman monthly rainfall-runoff model). This stream flow information is then used to determine the real-time Reserve requirements (based on the assurance rule outputs from a Reserve determination) and how best these can be met given other user requirements and the limitations of the available reservoir storage and operating rules. The operating rules will have been pre-calibrated using a water resources system yield model. The model output consists of recommended reservoir releases and/or curtailment levels that should be applied to water abstractors.

The three Pitman model versions represent different implementations of the widely used Pitman rainfall-runoff model (the version that includes surface-groundwater interaction routines developed by Hughes (2004)). The first version makes use of a single parameter set and generates a single streamflow output for each sub-catchment in the distribution system. The second (Parameter Exploration Tool) allows the user to specify ranges of parameter values and generate multiple outputs based on different combinations of parameter values. This version was the first attempt by the IWR to incorporate uncertainty analysis into water resources assessments using the Pitman model (Hughes *et al.*, 2010b). The last version of the model uses parameter inputs that consist of probability distributions that are sampled from during the multiple runs of the model (typically 5 000 to 10 000). The output consists of multiple random ensembles of streamflow estimations constrained by the probability distributions of the parameter values. Further work on different uncertainty configurations for the Pitman model is continuing within the Institute for Water Research and this version of the model is likely to be updated in the future.

The SPASIM-HDSF implementation of the *ACRU* model is described in more detail in Section 4 of this report.

The Revised Desktop Reserve model (RDRM) has been developed as part of a separate WRC project (K5/1856) that operated in parallel with the SPATSIM-HDSF project and will be completed at approximately the same time. The final report will be available at the end of 2011 and will contain full details of the model development and the use of the model. As the model description has not been published elsewhere at the time of writing this report, Figures 2-5 to 2-10, and the accompanying text, provide a brief overview of the structure and purpose of the model. It is designed to incorporate many of the developments in Reserve determination approaches that have emerged over recent years (Hughes and Louw, 2010) and specifically integrates hydrology, hydraulics and ecology information in a desktop type Reserve determination approach.

The main screen of the model is shown in Figure 2-5, and indicates that there are three main sub-models (hydrology, hydraulics and ecology) that are used to determine the low flow Reserve requirements. A relatively simplistic high flow approach is added and the final option is to determine the full Reserve and to review the report that is generated during each of the sub-models. The hydrology sub-model is shown in Figure 2-6, and the main purpose of this sub-model is to review the natural and present day hydrology data and to generate a value for the maximum baseflow in the critical months representing the wet and dry seasons.

The hydraulics sub-model, shown in Figure 2-7, involves the generation of a representative channel cross-section based on a number of parameters related to geomorphological zone, valley topography, catchment area and flood region. The internal algorithms of the model determine the hydraulic habitat conditions over the full range of water depths. These hydraulic habitats are an integration of depth and velocity and are used to inform the flow-stress relationship component of the ecological sub-model (Figure 2-8). The parameters and algorithms used in the hydraulic sub-model have been developed through extensive analysis of past ecohydraulics information gleaned from many Reserve determinations as part of Mr Ahmed Desai's PhD research programme.

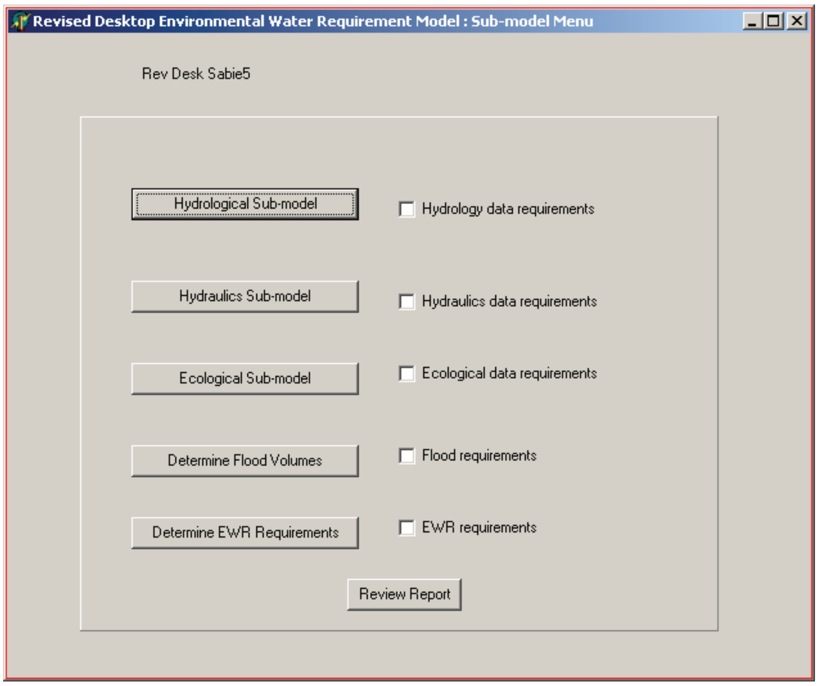

Figure 2-5 Main screen of the RDRM

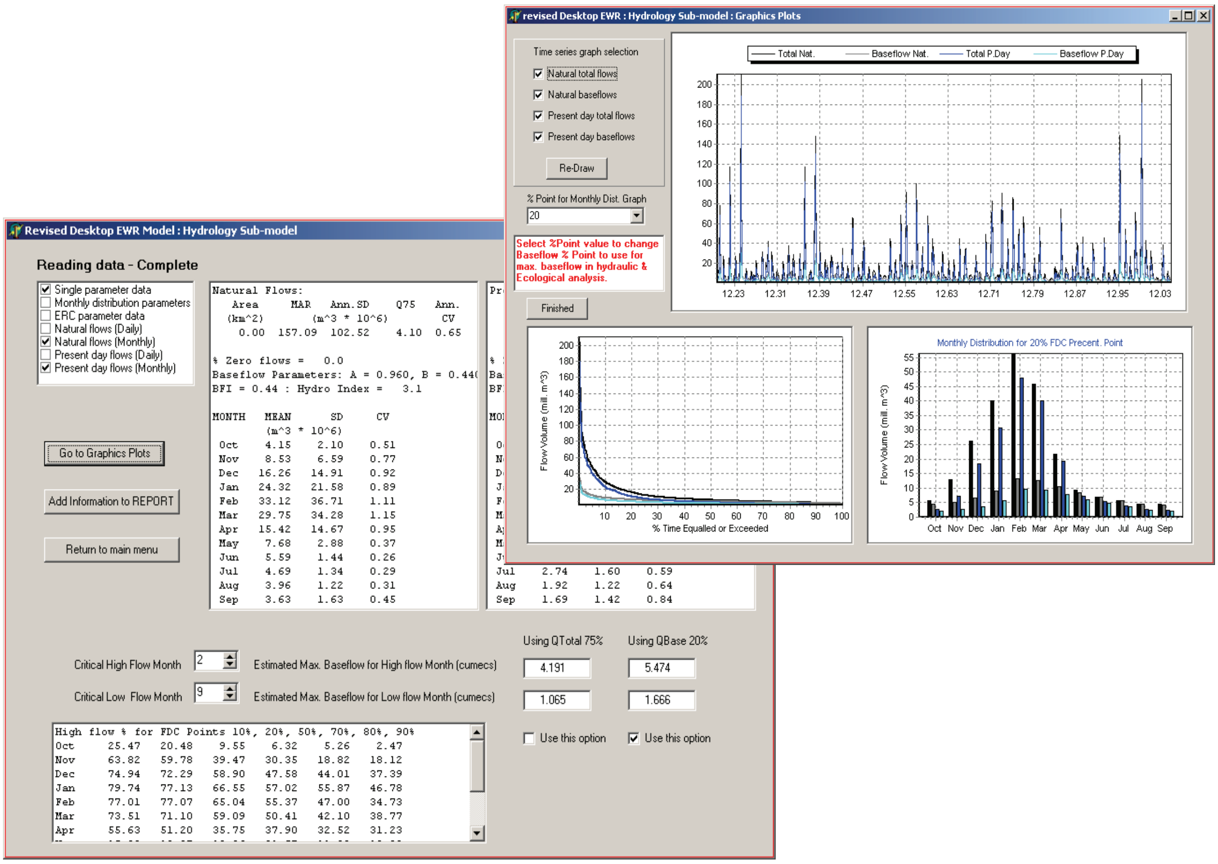

Figure 2-6 Screens of the hydrology sub-model

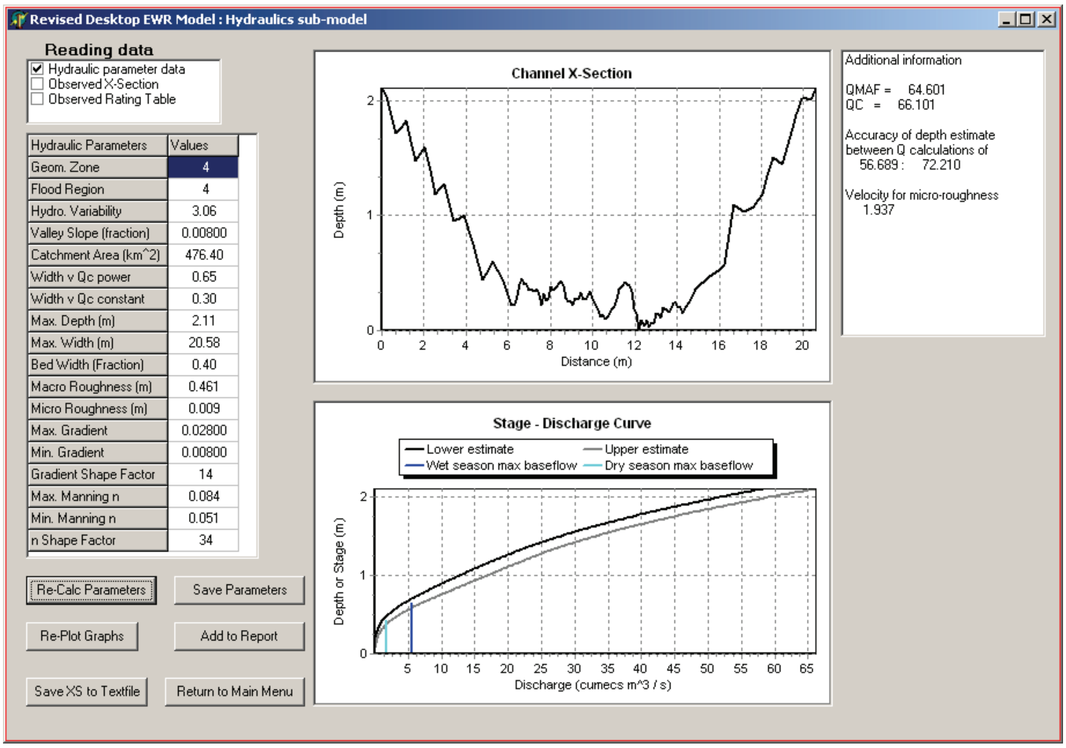

Figure 2-7 Hydraulics sub-model

The ecology sub-model, shown in Figure 2-8, is strongly aligned with the methods used within the Flow-Stressor Response approach to Reserve determinations. The basis of the model is to define flow-stress relationships (for wet and dry seasons) based on the availability of different hydraulic habitats at different flows rates within the range of zero to the maximum baseflow. These flow-stress relationships are used together with the hydrology time series of separated baseflow to define natural and present day ecological stress frequency curves. The stress frequency curves for the ecological categories are assumed to represent progressive increases in stress as the category drops from A to D. There are several user options that allow for perenniality or non-perenniality (in one or more seasons) and for aligning one of the ecological category stress frequency curves to the present day condition in both seasons (the other category curves are adjusted accordingly).

The approach that has been included for setting the high flow requirements is illustrated in Figure 2-9. The basis of this approach is very similar to that used in the original Desktop Reserve model, but with some minor modifications. The main point is that the annual requirements are distributed into individual monthly requirements using the proportion of the natural flow that can be considered to represent high flows (i.e. after removing the low flows using a baseflow separation method – see Hughes *et al.* (2003)). A secondary point is that the distributed annual requirements are assumed to be the high flow requirements with a frequency of exceedence of 50%, while less frequent floods are expected to require higher volumes, and higher frequency events are expected to require lower volumes (with no high flow events with frequencies of exceedence higher than 90%).

The final screen that includes the facilities to display the Reserve results (with or without high flows) and to save the data back to SPATSIM-HDSF is shown in Figure 2-10.

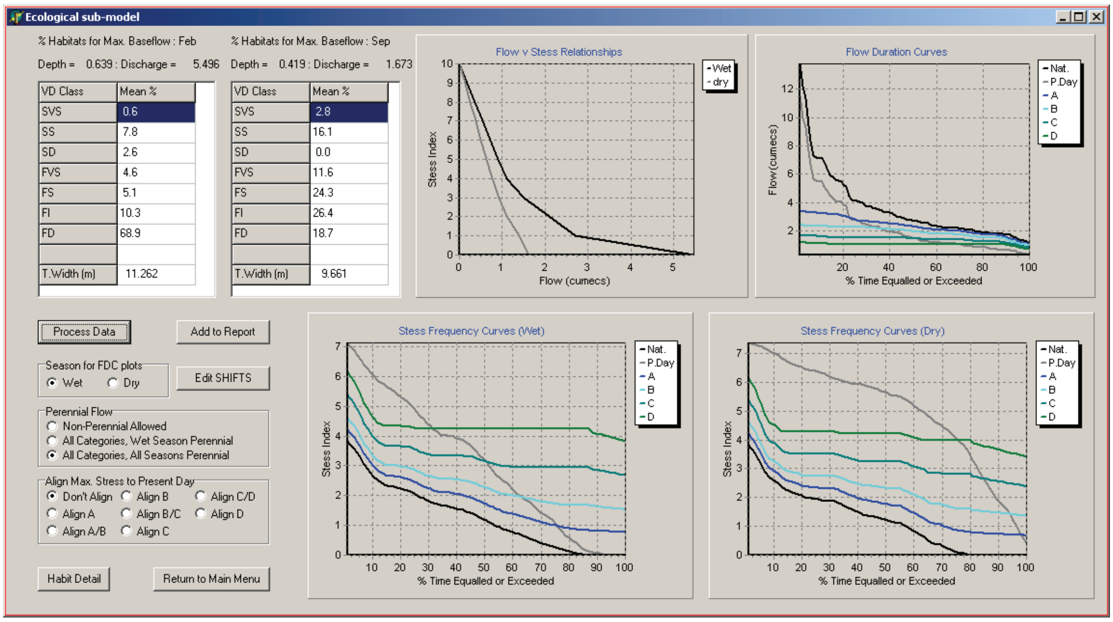

Figure 2-8 Ecology sub-model

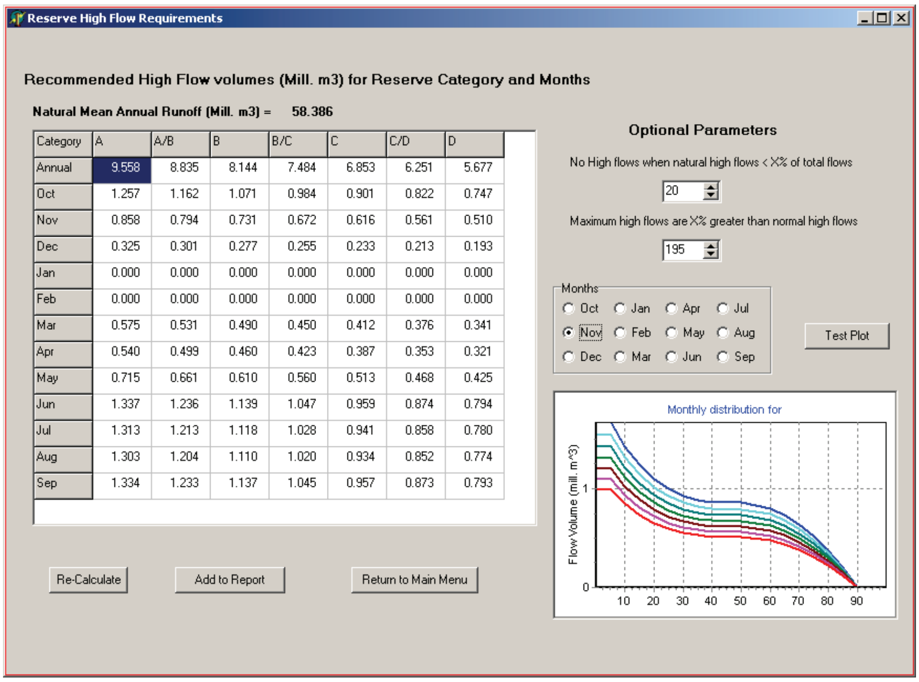

Figure 2-9 High flow requirement estimation screen

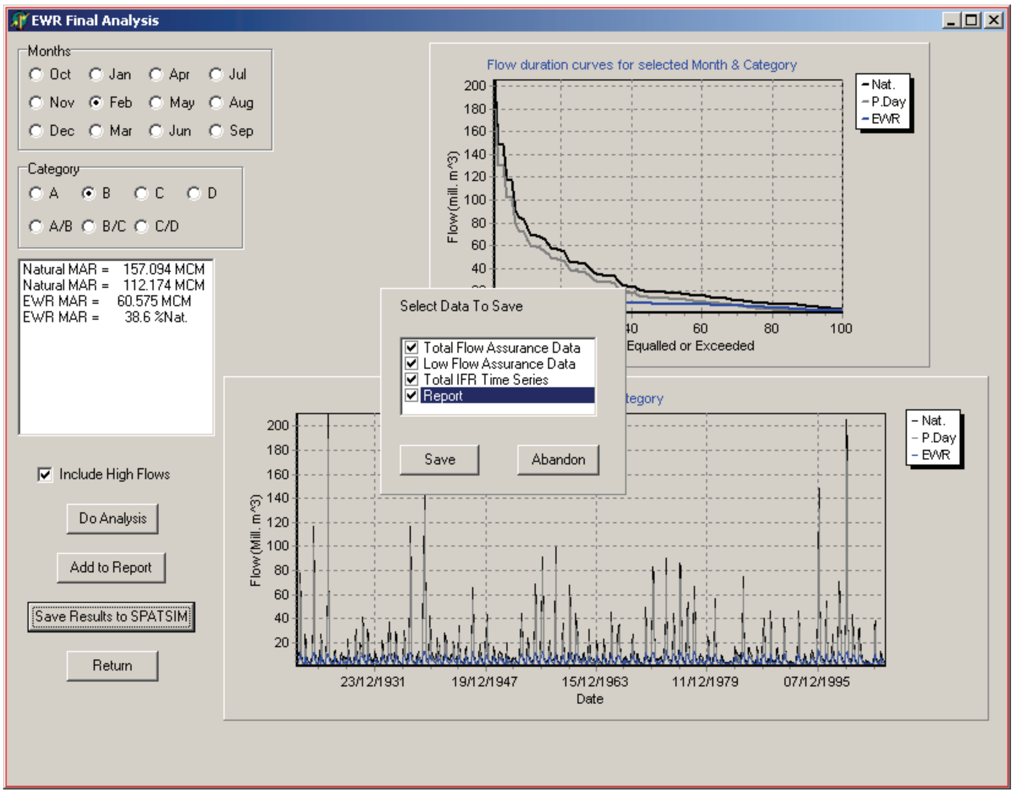

Figure 2-10 Final Reserve estimation screen

While there are many more models that are included as part of the original SPATSIM software package, many of these are 'research' tools that are either not expected to be used in practice or are still being developed. If any of these are later identified as being of value to a wider group of users then it is a relatively simple task to include them as part of SPATSIM-HDSF and this work will be undertaken by the Institute for Water Research as part of its commitment to the ongoing support of SPATSIM-HDSF as a tool to integrate research development and practice.

2.6 Links to External Data Formats

The SPATSIM-HDSF modelling framework enables time series data to be imported into a SPATSIM-HDSF database using the *Import T/S Data* utility in the *Attributes – Import Data* menu in the main SPATSIM-HDSF user interface. A report titled "*Identification of Appropriate Links Between HDSF and Selected DWA IT/Data Systems*" was compiled as part of this project to document the existing time series data import formats currently supported by SPATASIM-HDSF and then to identify any additional time series data formats used by the DWA from which users may need to import data into SPATSIM-HDSF. This report is included in Appendix H.3. The data format options previously supported by the SPATSIM-HDSF *Import T/S Data* utility include:

- *DWAF Daily Flow*,
- *Spreadsheet*,
- *HYMAS QOD*,
- *Water Quality Data*,
- *CLICOM – Daily*,
- *Continuous Text*,
- *Breakpoint*, and
- *Weather Bureau/CCWR Daily Rain*.

An investigation was conducted into the time series data formats used by DWA to disseminate data to interested parties. Based on the investigation it was recommended that the following formats be considered for possible inclusion in the SPATSIM-HDSF '*Import T/S Data*' utility:

- the text and CSV formats used by DWA for flow, rainfall and evaporation,
- the format used by the WMS for water quality data, and
- the RainIMS COUT file format.

Two additional formats have been added during this project. The first of these is the format used by DWA for the text file downloads of daily data (streamflow, rainfall and evaporation) from their website. The problems experienced with importing these data previously were related to the use of gaps (spaces) in the data fields when there were missing data. While some of the original import formats could be used (the 'continuous text' option, for example) it was necessary to pre-process the downloaded text files using a spreadsheet to fill in the missing data gaps. The new import format '*DWA Web Daily*' reads the text files directly and avoids any pre-processing. The format of the daily text files downloaded from the DWA website is assumed to contain 10 header lines (by default, but can be changed by the user) followed by the data contained in three columns. The first column is the date, the second the data values (streamflow, rainfall, evaporation depth or other – which may not be present if the data are completely missing) and the third the data quality code. The quality code is used to determine which of the data are imported directly and which are treated as missing data. The final screen of the data import enables the user to specify the type of data and the units.

The second format added is the comma separated water quality data available from the DWA website. The original water quality data import routine used the data in a similar format, but only after it had been imported into a spreadsheet. The data are breakpoint time intervals (unequal times between data points) and include values for many different water quality variables. The user is required to run the data import process for each individual water quality variable required as these data are stored in separate SPATSIM-HDSF attributes.

2.7 User Manuals and Training Materials

An important part of this project was the compilation of user manuals and training materials related to the SPATSIM-HDSF. However, it is highly recommended that potential users of the SPATSIM-HDSF modelling framework first attend a course introducing the framework.

SPATSIM-HDSF User Manual

The previous SPATSIM modelling framework was supported by documentation in Hypertext Markup Language (HTML) format describing the data structure, operation and associated models. In this project an updated and more comprehensive user manual was written for the new SPATSIM-HDSF version of the modelling framework. The user manual starts with some background information, development history and a general overview of the SPATSIM-HDSF modelling framework. The main components of SPATSIM-HDSF are then introduced, including the main SPATSIM-HDSF user interface, SPATSIM-HDSF database data model and the SPATSIM-HDSF external GIS tools. This is followed by a comprehensive "How To" section in which detailed instructions are provided for installation of the framework and how to use the various operations and tools within the SPATSIM-HDSF modelling framework. The models currently supported by SPATSIM-HDSF are briefly introduced with references to where further details about these models can be found. The user manual ends with a section containing information for software developers, including the design details of the SPATSIM-HDSF database data model, discussed in Section 2.1, and the Data Access library, discussed in Section 2.2. The SPATSIM-HDSF User Manual is included in Appendix A [also in Appendix I.2].

TSAnalysis User Manual

A comprehensive user manual was also created for the TSAnalysis library of time series analysis tools discussed in Section 2.4. This user manual starts with a brief introduction describing the purpose of this library. The general functionality common to all the tools is then explained with detailed operating instructions. Each of the eight tools is then presented in a separate chapter, where each chapter starts with an introduction to each tool followed by detailed instructions regarding the operation of the relevant tool. The TSAnalysis User Manual is included in Appendix C [also in Appendix I.2].

SPATSIM-HDSF External GIS Tools User Manual

A set of external GIS tools was created as an extension for ArcGIS was developed in WRC project K5/1490 to enable data stored in spatial features in a SPATSIM-HDSF database to be viewed, edited and analysed in ArcGIS. A user manual was created for these SPATSIM-HDSF external GIS tools in WRC project K5/1490 and is included in Appendix B [also in Appendix I.2].

Training Materials

On the basis of past experience, it has been found that the best way to learn how to use software such as SPATSIM-HDSF, is through a hands-on course in which the focus is on the basic principles and how to apply them. However, there are times when reference has to be made to some supporting documentation that includes the SPATSIM-HDSF User Manual (see Appendix A [also in Appendix I.2]) and the National RDM Database User Manual (see Appendix D [also in Appendix I.2]) that refers to the specific application of SPATSIM-HDSF for undertaking Reserve studies. The need for additional training material largely depends on the individual and how frequently they use the system. Post-graduate students at the IWR are using the old version of SPATSIM on a daily basis to support their research activities and are completely familiar with the software after a short initial introduction and some personal experience. Other users who apply the software less frequently would certainly benefit from additional documentation. However, experience also suggests that the requirements for such a document are often individual.

A document titled "*SPATSIM-HDSF: A Step-By-Step Training Guide*" (see Appendix E [also in Appendix I.2]) was developed as training material for the SPATSIM-HDSF workshop held on 11 and 12 October 2011. This training material was developed for the purpose of training users of the National RDM Database application of SPATSIM-HDSF, but could also be used for more general training in the use of SPATSIM-HDSF.

2.8 Workshops

During the course of the project three workshops were held with the aim of introducing SPATSIM-HDSF to new users and updating existing SPATSIM users regarding the new SPATSIM-HDSF version of the modelling framework.

The first workshop was held on 9 March 2009 at the Water Research Commission in Pretoria. A selection of individuals involved in water resources planning, management and modelling were invited to attend the workshop. Many of the delegates that attended the workshop work for, or with, the DWA. Many of the delegates from the Resource Directed Measures (RDM) section of DWA were existing users of the previous SPATSIM version of the modelling framework. A report containing details of this workshop is included in Appendix H.4.

The second workshop was held on 18 and 19 October 2010 at the DWA Roodeplaat Training Centre near Pretoria. The 28 delegates were mostly from DWA, but also included delegates from Department of Agriculture, Umgeni Water, University of Witwatersrand, University of Pretoria, and some consultants. Some of the delegates were existing users of the previous SPATSIM version of the modelling framework. A report containing details of this workshop is included in Appendix H.5. There were three major problems with this workshop from the point of view of the project team. The first problem was that the group was far too large and this prevented effective interchange between the delegates and the main presenter. This problem was partially offset by having some experienced users attending as delegates. The second was that the course was designed to be fully interactive so that the delegates could be presented with the principles of use of the software including some example applications, after which they were expected to repeat the exercise and get some hands-on experience. However, the room was long and thin so that many of the delegates could not see the front screen very clearly and therefore could not follow the presentation. The third problem was that some of the delegates did not have an immediate use in mind for SPATSIM-HDSF and therefore there was very little context. A subsequent visit to the IWR by some of the Eastern Cape DWA delegates and their colleagues (a total of 4 people) was much more valuable. It was far easier to set up examples that were directly relevant to the users and there was a much more focused exchange of questions and answers.

The lessons to be learned from these experiences is that the training groups should be relatively small (no more than 8 people), the facilities need to be adequate for interactive training and the training should be focused on the expected applications. If there are a larger group that have a range of applications then it would be sensible to run through the basic functionality of the software with the group as a whole, but then break into smaller groups for more directed training and practice. This of course means that there would need to be more than one presenter.

The third workshop was held on 11 and 12 October 2011 at the offices of BKS in Hatfield, Pretoria. The 10 delegates were mostly from the RDM section of DWA, but also included one delegate from IWMI. Some of the delegates were existing users of the previous SPATSIM version of the modelling framework. A report containing details of this workshop is included in Appendix H.7.

3 NATIONAL RDM DATABASE

The National RDM Database is a specific application of SPATSIM-HDSF that has been created for the RDM Directorate of DWA to use as one of the main tools for undertaking Reserve determinations and storing the information for future use. The database has been based on the old SPATSIM version that has been used during many Reserve determinations that included the Institute for Water Research as part of the project team. Additional data from other Reserve studies has been included where it has been made available to the project team. The details of the database and the way in which SPATSIM-HDSF has been set up are not repeated here as they are fully documented in a separate report (Hughes *et al.*, 2010a) included in Appendix D [also in Appendix I.2]. There are 189 Reserve study sites included as part of the 'EWR Sites' feature of the database (Figure 3-1), however, the amount of information that is available for these varies considerably and has depended upon what information was made available to the project team. In some cases the information consists of all the detailed input and output information, used or generated through a Reserve study involving the Flow-Stressor Response approach. In other cases the information only consists of the final Reserve output table (extracted from a report document) and some of the input information (e.g. time series of natural flows). In the latter case it is possible to use these data to set up a run of the Desktop Reserve model and generate Reserve requirement time series and assurance tables. However, it is necessary to assume that some of the default regional parameters of the Desktop Reserve model are applicable. A further feature ('Quat_EWR_Sites') has been added to account for some limited information that was supplied to the project team about two basin-wide extrapolation studies (one in the Olifants River and one in the Mzimkulu River).

The database has been setup with most of the features and attributes that would be typically required for a Reserve study regardless of the level (desktop to comprehensive) of determination. The manual provides guidelines for the use of the database and describes the various attributes and how they would be used. The manual also lists the various models and data analysis tools that have been included (also see Section 2.5 of this report). A further model (the Revised Desktop Reserve Model – RDRM) has been recently added through a link with another WRC project (K5/1856). This model is designed as a desktop Reserve determination approach that explicitly includes the links between hydrology, hydraulics and ecology, while the old Desktop Reserve model was mostly based on regional parameters and hydrological characteristics. The model is not described in detail within this report, but the final report on the details of the model is expected to be available before the end of 2011.

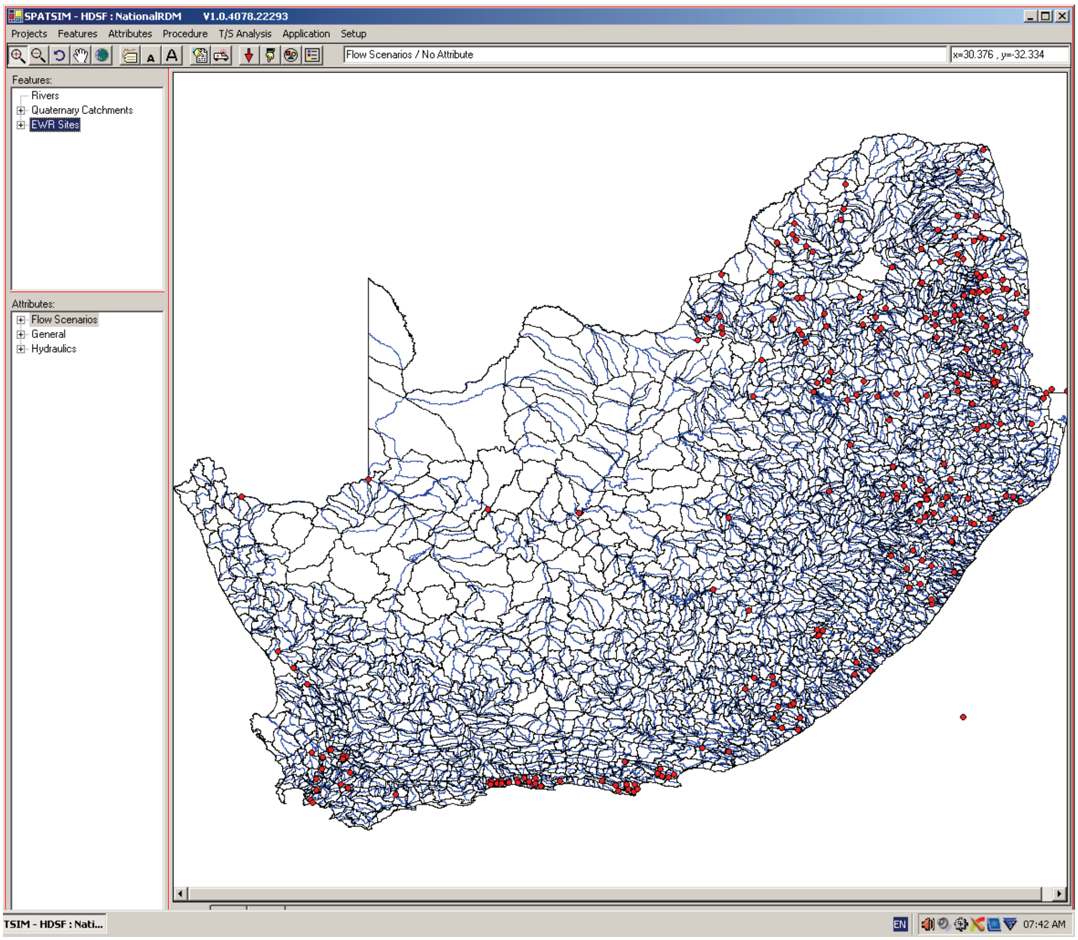

Figure 3-1 Screen image of the National RDM application of SPATSIM-HDSF showing the EWR sites

While there was very little software or model development required for the SPATSIM-HDSF project, the earlier version of the database was extensively reviewed for the accuracy of the content and the clarity of the names of the attributes. The database was also 'cleaned' up and any superfluous information removed. This exercise allowed for many of the data import and export processes that form part of SPATSIM-HDSF to be checked and made as efficient as reasonably possible. Some software changes were also made that improve the efficiency of setting up the same model (e.g. the Desktop Reserve model) for multiple sites and for the same site with different sets of attributes (i.e. running the Desktop Reserve model multiple times for different ecological Reserve categories). These two tasks are now much easier to achieve within SPATSIM-HDSF than they were in the earlier version of SPATSIM. The process of setting up multiple runs of the model is illustrated in Figure 0-1. The user starts by clicking on all the required spatial objects (i.e. EWR points) followed by associating the model requirements with the attributes available in the database. When saving the model setup, the user selects the 'Create Multiple Model Runs' option (Figure 0-1) and is prompted for a generic model run name to which is added the names of the selected spatial objects and several model runs are created. These can then be accessed individually in the normal way.

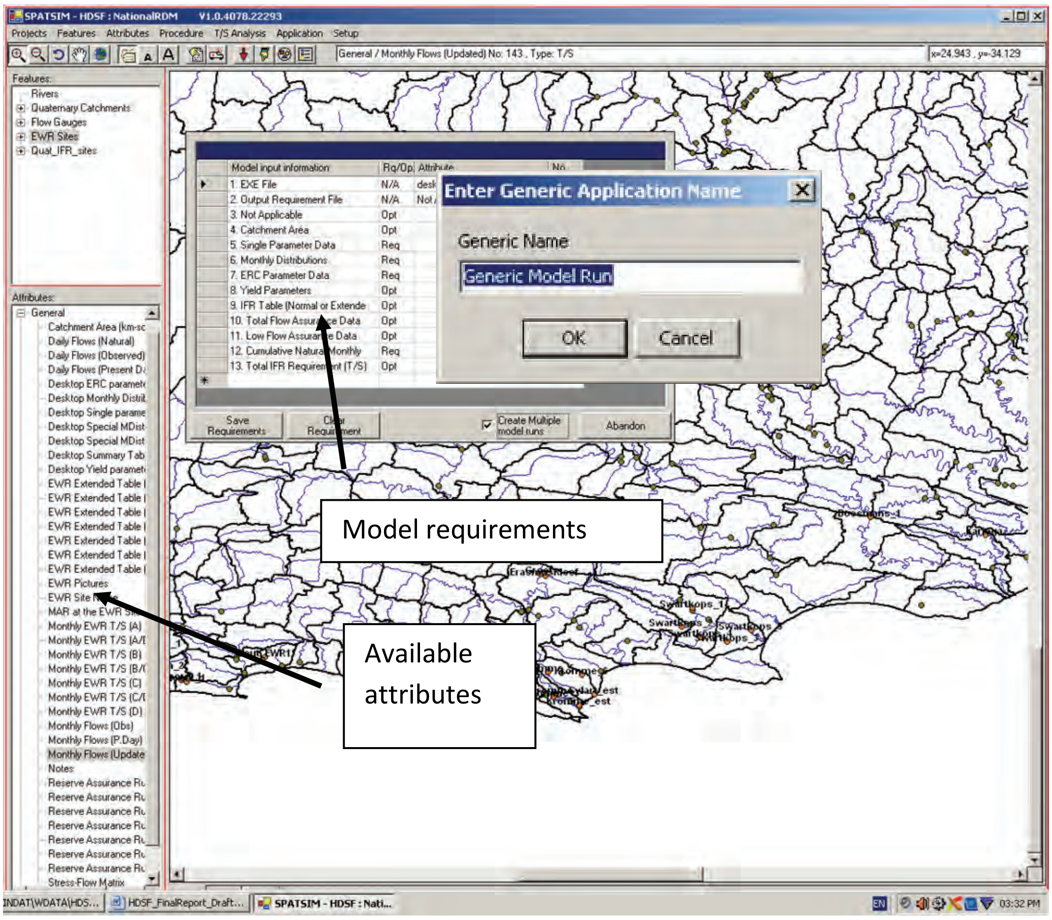

Figure 0-1 Illustration of the use of the option to create multiple model runs

One of the issues associated with managing a database of this type is related to maintaining the integrity of the master database (presumably held by the RDM Directorate of DWA) whilst also making the database available to the service providers who are tasked with Reserve assessments studies. Some software changes were therefore added to SPATSIM-HDSF that allows for a copy of the National RDM database to be 'checked-out' to a service provider and then 'checked-in' when the Reserve study has been completed and the main database requires updating. This is not a simple task as it is necessary to ensure that the copy of the database has not been corrupted during use, nor that changes have been made accidently to parts of the database that were not part of the new study. This means that a great deal of ‘manual’ checking is essential and the software developments have taken this into account. One of the first software changes required was to add a ‘Client ID’ field to parts of the database so that the ‘ownership’ of added data could be identified. The checks that are used to preserve the integrity of the database are mostly based on this ‘Client ID’ and the date and time at which information was added to (or updated in) the database. The steps in the process for ‘checking-in’ are detailed in the bullet points below:

- Any additional spatial objects are checked before being included. Any data associated with those that are rejected will not be added to the master copy of the database.
- Any new attributes associated with any of the spatial features are checked before being included. Any data associated with the rejected attributes will not be added to the master copy of the database. The accepted attributes are added to the list of attributes contained in the master database.
- The remaining checks are based on identifying ‘new’ information and deciding, in the most efficient way possible, what to include or exclude.

All of these procedures were added towards the end of the project and have not been rigorously tested using a group of user stakeholders. One of the important issues that remains to be assessed is whether or not the user group within the RDM Directorate of DWA will make use of these new procedures. They are certainly more efficient (and secure) than saving from the revised copy of the database and copying back to the master copy. However, they will still require a substantial amount of concentrated and informed decision making, particularly with large Reserve studies. The effort required to import data from a copy of the database will be proportional to the skill and experience that the team of service providers have available to them in terms of operating the database. It is therefore essential that all of the service providers are familiar with the proper use of the database and do not misuse it when undertaking a Reserve study. A simple example is that they should always use the default attributes for importing and generating data (as explained in the National RDM manual) where possible. If they do not, then there will be a large number of additional attributes in the copy that are duplicates of the one in the master. If the integrity of the master database is to be maintained, all of these would have to be rejected, meaning that most of the Reserve study results would not be saved to the master database.

It has not been possible to develop any formal guidelines for the use of the ‘check-out’ – ‘check-in’ procedures as these will largely depend upon how DWA staff would like to operate the system. It is therefore essential that DWA review the process (with assistance from the project team) and develop some recommendations about their operational procedures. The project team at the IWR will then compile some formal written guidelines and, where necessary, modify the software to be compatible with DWA operational procedures. This can be achieved after the project has been finalised (and at no cost to DWA) as part of the project teams commitment to finalising the software.

4 *ACRU* DEVELOPMENT

As part of WRC Project K5/1490 the *ACRU* agrohydrological model was modified and a new model input structure was developed to include the *ACRU* model as one of the SPATSIM-HDSF compliant models available to users. An *ACRU* Menu Converter application was developed to enable users to convert existing *ACRU* model input files to the new model input structure with data values stored in a SPATSIM-HDSF database. A prototype *ACRU* model input configuration editor was developed to provide a graphical user interface that would enable users to populate the new *ACRU* model input files. An *ACRU* Interface form was developed to enable users to access *ACRU* related tools and initiate *ACRU* model runs from the SPATSIM-HDSF modelling framework. Further details of this work can be found in Clark *et al.* (2009). As part of the current project these supporting software tools for the *ACRU* model were debugged and further developed. The *ACRU* model itself together with its supporting software tools forms the *ACRU 4* modelling system, as shown in Figure 4-1. The installation files for the *ACRU 4* modelling system are included in Appendix I.3.

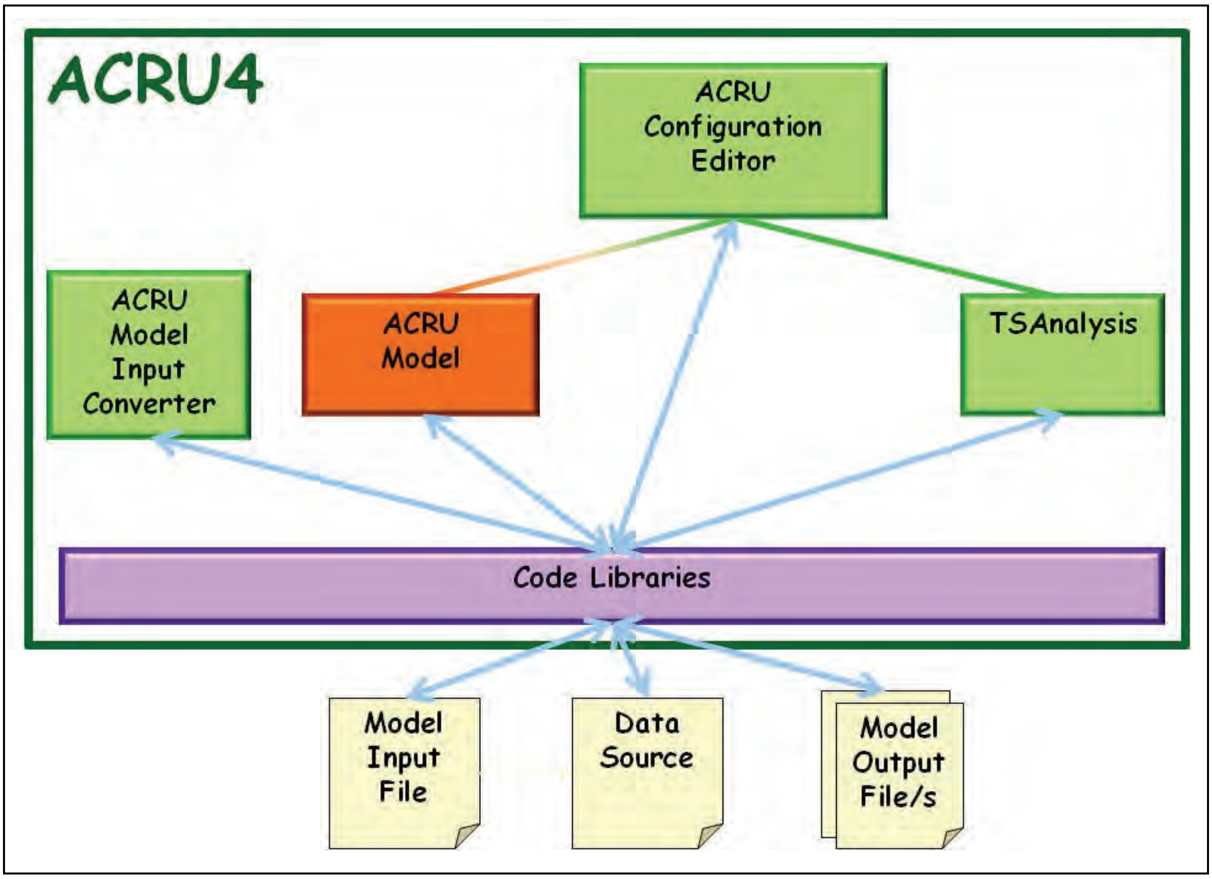

Figure 4-1 Simple schematic diagram of the *ACRU 4* modelling system

4.1 SPATSIM-HDSF *ACRU* Interface

The *ACRU* model is a complex model with a large number of potential variables and parameters and for this reason cannot be set up within the SPATSIM-HDSF modelling framework in the same manner as for other models included in SPATSIM-HDSF. The *ACRU* model may be setup and run from the SPATSIM-HDSF modelling framework by selecting the *Application / ACRU Model* menu item to display the *ACRU Interface* form shown in Figure 4-2. The *ACRU Interface* form provides access to three options: (i) to run the *ACRU Configuration Editor* application, (ii) to run an existing setup of the *ACRU* model directly from SPATSIM-HDSF, and (iii) to run the *ACRU* Menu Converter application.

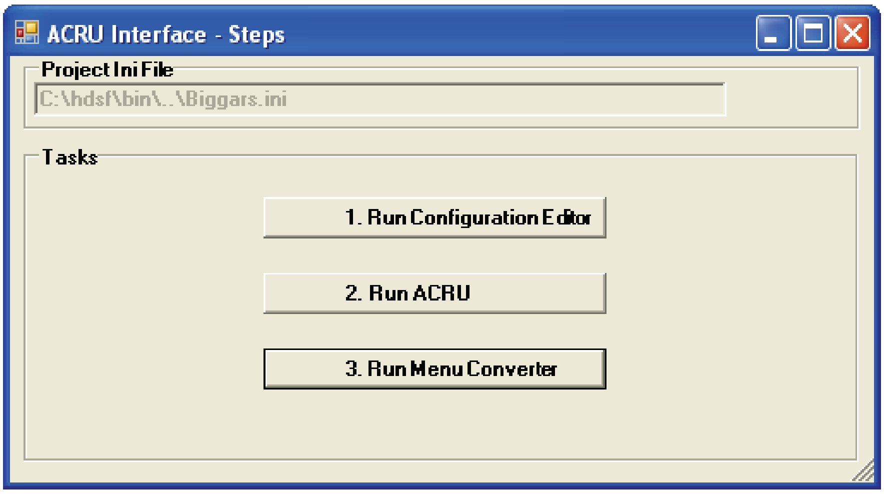

Figure 4-2 Example of the *ACRU Interface* form

In this project several minor bugs in the code of the *ACRU Interface* form have been resolved and the form has been further developed. A summary of the changes made to the *ACRU Interface* form is shown in Table 4-1.

Table 4-1 Summary of changes made to the *ACRU Interface* form

Description
Added code to find the *ACRU* related executable files relative to file path for the SPATSIM-HDSF application.
Added a button and code to enable the *ACRU* Configuration Editor application to be run
Removed the button that previously enabled the *ACRU Output Builder* application to be run, as this application must now be run from the *ACRU* Configuration Editor application.
Modified the code used to run the *ACRU* model to prevent bugs when calling the Java code with a parameter list.
Modified code to pass parameters to the *ACRU_Interface_dll* library

4.2 *ACRU* Configuration Editor

As reported in Clark *et al.* (2009) a prototype model input configuration editor, known as the Configuration Editor was developed. The Configuration Editor was developed primarily for the *ACRU* model, but designed in such a way that it could be applied to other hydrological models if a suitable configuration schema file was created for each model.

In this project the prototype Configuration Editor was extensively further developed to provide a flexible and extensible user interface for populating, editing and viewing model input data. The Configuration Editor has been successfully applied for the *ACRU* model, as shown in Figure 4-3, and is now used by all users of the *ACRU 4* version of the *ACRU* model. In addition to further developing user interface functionality, one of the main areas of further development was that the internal data model used within the Configuration Editor was changed to the object-oriented data model, using Extensible Markup Language (XML), developed for the *ACRU* model. This data model is based on two XML schema files: (i) a ModelData schema describing the structure of model input data and data references, and (ii) a ModelConfiguration schema describing the structure of the model specific configuration data which includes metadata about model input variables used by the Configuration Editor. Other further development is summarised in Table 4-2. Reports describing the details of the further development of the Configuration Editor can be found in Appendix H.1 and Appendix H.2. The *ACRU 4* User Manual included in Appendix F [also in Appendix I.4] contains detailed descriptions of how to use the Configuration Editor for the *ACRU* model.

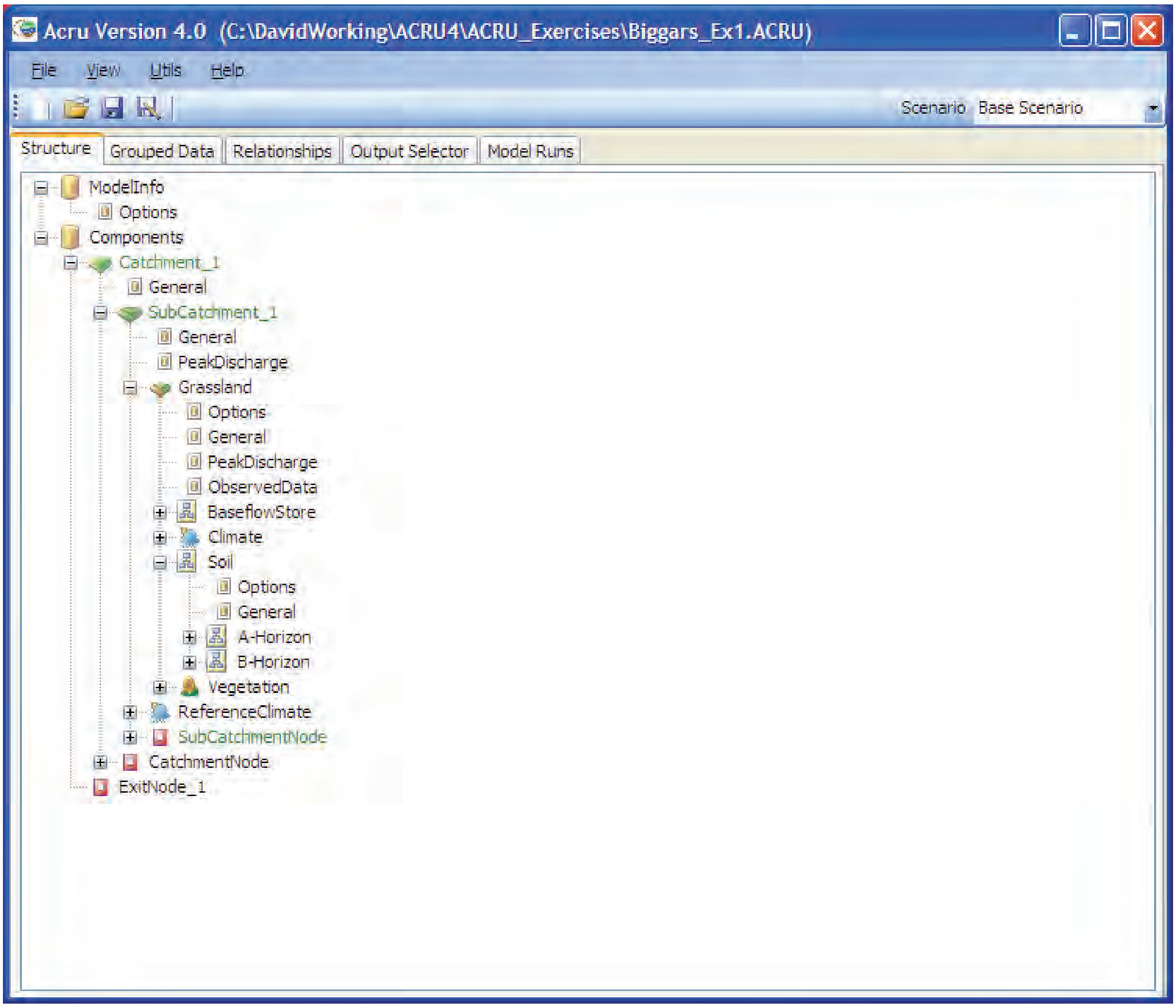

Figure 4-3 Example of the *ACRU* Configuration Editor application

Table 4-2 Summary of changes made to the Configuration Editor application

Description
The internal data model used within the Configuration Editor was changed to the object-oriented XML data model developed for the *ACRU* model.
Made changes to the *Grouped Data* tab to enable Component types to be grouped in a hierarchical manner according to the Component configuration specified in a ModelConfiguration XML file.
The inclusion of a *Structure* tab to display the Component elements and their hierarchical parent-child tree structure in addition to the *Grouped Data* tab on which the Component elements are grouped by ComponentType.
The inclusion of a *Relationships* tab to enable relationships between Component elements to be added and edited.
The inclusion of a *Scenarios* tab to enable scenarios to be added and edited.

Description
The inclusion of an *Output Selector* tab to enable model output variables to be selected, and the format and output destination to be specified.
The inclusion of a *Model Runs* tab to enable model runs to be added and edited.
The inclusion of forms enabling array and time series data to be viewed and edited.
In the Configuration Editor, Display Rules are rules that specify which model variables and parameters should be enabled for editing based on user selected model options, and Data Rules are rules that check the validity of the data values specified for model variables and parameters. The changes to the internal data model in the Configuration Editor required that changes be made to the manner in which display and validation rules operated, and required that they be changed from the simple data row referencing method to a more complex referencing method that searches for relevant Component objects by means of a relative path through the Component hierarchy tree. Changes were also made to the manner in which the data validation results are displayed.
The implementation of lookup tables for Data elements for which a finite set of values exist.
The inclusion of forms and code classes to enable references to data stored in external data repositories to be setup, and read data from and write data to, these repositories. The data repositories currently included are: SPATSIM-HDSF databases implemented in Microsoft Access, *ACRU* Single format, *ACRU* Composite format and *ACRU* CompositeY2K format.
Added code to enable edited model input values to be saved back to ModelData XML files and SPATSIM-HDSF databases.

4.3 *ACRU* Menu Converter

The *ACRU* Menu Converter application described in Clark *et al.* (2009) was developed to enable *ACRU* model input data files stored in the text file format used by the *ACRU 300* series version of the model to be converted to the XML based model input files used by the *ACRU 4* version of the model, with the option to reference data stored in a SPATSIM-HDSF database.

In this project a few minor bugs in the code of the *ACRU* Menu Converter have been resolved, changes have been made to improve the performance of the application and the application has been further developed. The revised *ACRU* Menu Converter application is shown in Figure 4-4. A summary of the changes made to the *ACRU* Menu Converter is shown in Table 4-3.

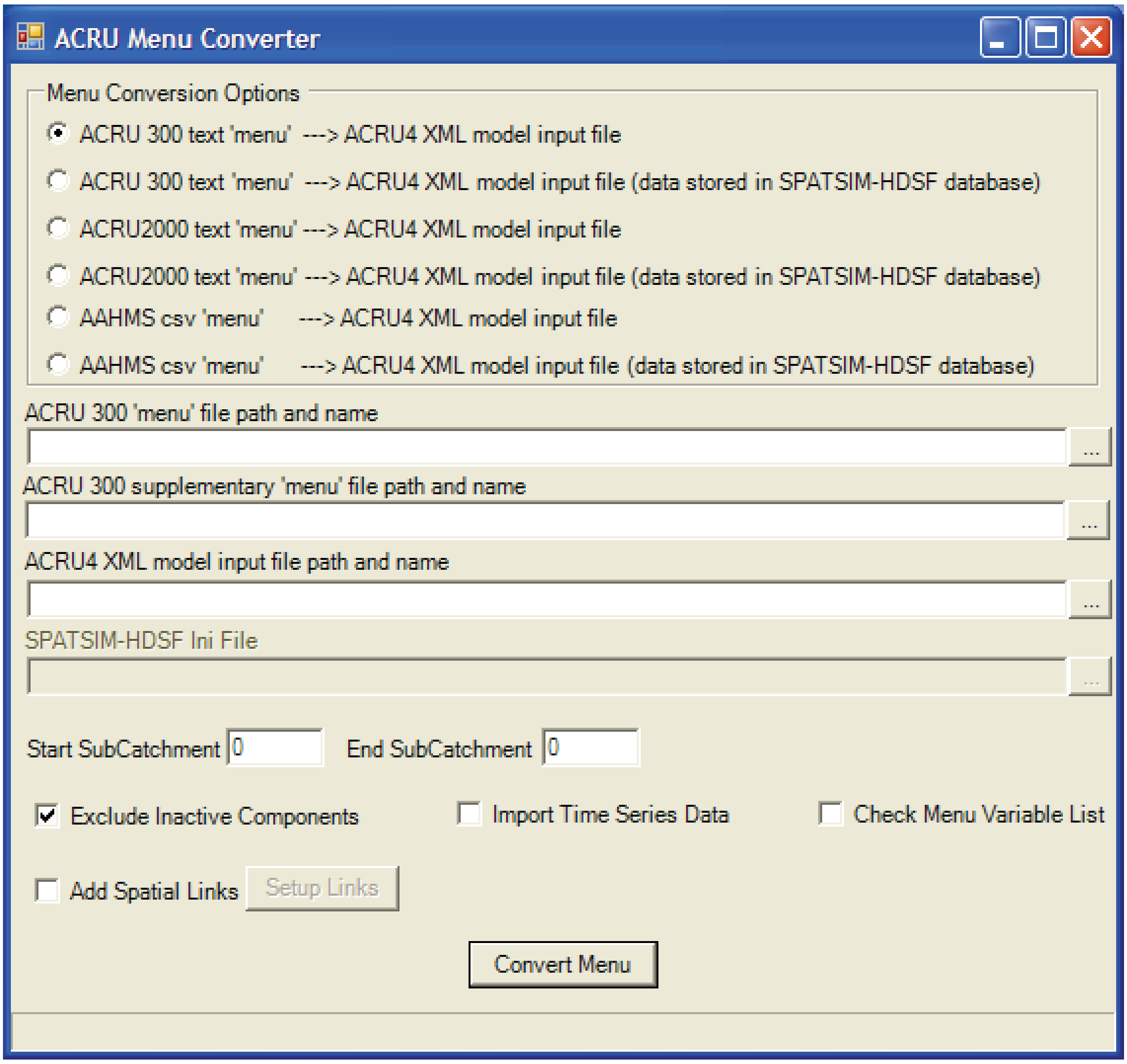

Figure 4-4 Example of the *ACRU* Menu Converter application

Table 4-3 Summary of changes made to the *ACRU* Menu Converter application

Description
Added code to enable conversion of model input files for the *ACRU*2000 version of the model to the XML based model input files used by the *ACRU 4* version of the model.
Added code to enable conversion of model input files stored in CSV format by the *ACRU* Agrohydrological Modelling System (AAHMS) to the XML based model input files used by the *ACRU 4* version of the model.
Added a checkbox control and code to enable inactive Components within a legacy model setup to be excluded from the converted model input file.
Added functionality that enables users to associate a selected ESRI shape file with a particular *ACRU* Component type, so that these can be represented as spatial features in SPATSIM-HDSF. Previously the physical entities represented in legacy *ACRU* model input files were as converted as non-spatial features as the physical entities did not have any spatial context.

Description
Modified code to improve speed of conversion, especially for large model input files.
Modified code to resolve a problem related to accessing Microsoft Access databases in some circumstances.

4.4 *ACRU* Model and Model Input File Structure

It was not intended within this project to make any substantial changes to the design of the *ACRU* model structure, the hydrological process modelled, or the structure of the model input data and configuration files. However, some minor modifications were made to the model and the model input data and configuration files as shown in Table 4-4.

Table 4-4 Summary of changes made to the *ACRU* model and input files

Description
Creation of a set of serialisation objects to read the XML model input files, which resulted in a significant improvement to the speed at which these files are read by *ACRU* model at the start of a simulation.
Modified the XML model input file to include a Boolean attribute named *Active* within a *Component* element to enable users to select a subset of the full set of subcatchments to be run. Using the Configuration Editor, *ACRU* users may use the *Active* attribute to make a subcatchment or other Component element active or inactive for a specific scenario and model run.

4.5 User Manuals and Training Materials

User manuals and training manuals for the *ACRU* model have been compiled as part of this project and are briefly described below. It is highly recommended that potential users of the *ACRU* model first attend a course.

ACRU 4 User Manual

A completely new user manual has been developed for the *ACRU 4* modelling system. This user manual starts with a brief introduction to the *ACRU 4* modelling system followed by an explanation of the key concepts of the system. The *ACRU* Configuration Editor is covered in detail, starting with an overview of the software, and followed by a comprehensive, “How To”, section in which detailed instructions are provided regarding how to use the various operations and tools within the user interface. The *ACRU* Menu Converter application is briefly described. An important part of the user manual is the comprehensive set of exercises which guide the user through using the *ACRU 4* Configuration Editor to configure the *ACRU* model for a selected catchment, running the *ACRU* model, analysis of model output using the TSAnalysis library of time series analysis tools, and using the *ACRU* Menu Converter utility. The *ACRU 4* User Manual is included in Appendix F [also in Appendix I.4].

Manual for Running the *ACRU* Model from SPATSIM-HDSF

The *ACRU Interface* form described in Section 4.1 enables the *ACRU* model to be setup and run within SPATSIM-HDSF and a short user manual has been created to guide users in how to use this form. A brief description of the *ACRU Interface* is followed by a comprehensive exercise which guides the user through using the *ACRU 4* Configuration Editor from within SPATSIM-HDSF to configure the *ACRU* model for a selected catchment using data stored in a SPATSIM-HDSF database. The Manual For Running The *ACRU* Model From SPATSIM_HDSF is included in Appendix G [also in Appendix I.4].

***ACRU* Training Materials**

Typically *ACRU* training courses start with an introduction to the *ACRU* model itself and the hydrological concepts on which it is based, this is followed by an introduction to the *ACRU 4* modelling system, after which the users are guided step-by-step through a set of practical exercises in which they use the *ACRU 4* modelling system to setup and run the *ACRU* model for a selected catchment. A set of presentations used within the School of BEEH to introduce the *ACRU* model and the hydrological concepts on which it is based, is included in Appendix I.4. A presentation created to introduce the ACRU 4 modelling system is also included in Appendix I.4. This presentation includes a brief introduction to the ACRU 4 modelling system followed by an explanation of the key concepts of the system. The practical exercises are part of the *ACRU 4* User Manual included in Appendix F [also in Appendix I.4].

4.6 Workshops

During the course of the project two workshops were held with the aim of introducing the *ACRU* model to new users and updating existing *ACRU* users regarding the new *ACRU 4* modelling system.

The first workshop was held 23 July 2010 at the University of KwaZulu-Natal in Pietermaritzburg. The course was open to staff and postgraduate students in the School of Bioresources Engineering and Environmental Hydrology (BEEH). This workshop served two main purposes: (i) to update existing *ACRU* users within the School of BEEH, regarding new developments, and (ii) as a test run for the second workshop held in October 2010.

The second workshop was held on 20 and 21 October 2010 at the DWA Roodeplaat Training Centre near Pretoria. The 23 delegates were from DWA, Department of Agriculture, Umgeni Water, University of Witwatersrand, University of Pretoria, University of Stellenbosch, the CSIR, and some consultants. Some of the delegates were existing users of the *ACRU* model. A report containing details of this workshop is included in Appendix H.6.

5 USER SUPPORT

During the course of the project, user support was provided by both the IWR and the School of BEEH, to users of the SPATSIM-HDSF modelling framework, users of the *ACRU* model and users of other models within the SPATSIM-HDSF modelling framework. This user support was provided to individuals within the DWA, CSIR, various universities and several consultants. Substantial support was also provided to Hydrology 3rd Year, Hydrology Honours and Agricultural Engineering 4th Year students in the School of BEEH, who in turn provided valuable feedback regarding the *ACRU 4* modelling system.

6 CONCLUSIONS

Integrated water resources management is a key requirement of the National Water Act of South Africa (Act 36 of 1998) and this has created a requirement for integrated water resources modelling. One aspect of integrated water resources modelling is the development of hydrological modelling frameworks to provide a modelling environment that facilitates the integration of models, providing a common data model and common data editing and analysis tools for use by a suite of models associated with the framework. The SPATSIM-HDSF framework is one such framework. An important part of this project has been the further development and stabilisation of the restructured SPATSIM-HDSF modelling framework developed as part of WRC Project K5/1490. An even more important outcome from this project has been the development of a comprehensive user manual for the SPATSIM-HDSF modelling framework and training of new and existing users of the framework through three workshops.

The previous version of SPATSIM has been used to support a large number of Reserve determination studies in the past and a great deal of data had already been incorporated into a single application of the software. The SPATSIM-HDSF project represented an opportunity to consolidate this database and transfer it to the new database structure, as well as adding further information that was previously not included. Some of the software changes that have been made to improve the functionality of SPATSIM-HDSF were motivated by comments from various users of the previous version. These include more efficient ways of setting up multiple runs of the Desktop Reserve model across different sites (spatial objects), an important change for those users who are tasked with estimating low-confidence Reserves at many points within a river basin.

The original objective of creating a National RDM database was to facilitate the management of Reserve studies and the results that are generated by the RDM Directorate of DWA. Many of these results are generated by different teams of consultants (service providers) and the full details of the studies have not always been returned to DWA for archiving (in many cases only the final results and the written report have been submitted to DWA). This means that it is not always a simple task to reproduce the results and make some changes if new information comes to light in the future, or if the management objectives for a specific river change in the future. The SPATSIM-HDSF project has attempted to address this issue by providing a facility that can be used by DWA to manage the data used in and generated by Reserve studies. In brief this includes a facility for consultants to ‘check-out’ the most up-to-date version of the database with a unique identification code. Upon completion of the Reserve study, the consultant will then be required to ‘check-in’ their modified version of the database. The new facility allows DWA to run various integrity checks to ensure that the master database is not corrupted by errors or mistakes made by an individual consultancy team and that the master is only updated with legitimate information appropriate to the specific Reserve study. The value of this new facility and how it will be used in practice still needs to be assessed and this can only be done once DWA start to use the system.

The incorporation of the *ACRU* agrohydrological model as one of the models available within the SPATSIM-HDSF modelling framework as part of WRC Project K5/1490, prompted a complete structuring of the structure of the model input files used to provide data to the *ACRU* model. As part of this project the structure of the *ACRU* model input files has been further developed and stabilised. In addition this project has resulted in significant further development and improvement of the tools associated with the *ACRU* model, especially the Configuration Editor, but also the *ACRU* Menu Converter and SPATSIM-HDSF *ACRU* Interface. In addition this project has resulted in the development of a comprehensive user manual for the *ACRU 4* modelling system and training of new and existing users of the model through two workshops.

In conclusion, the main objectives of the project, including further development and stabilisation of the SPATSIM-HDSF modelling framework, development of user manuals and training materials, training workshops, user support, improvement of models and development of RDM related tools have all been met. Significant improvements to the SPATSIM-HDSF modelling framework and the *ACRU 4* modelling system have been made, and both are now in use and have reached a stable stage of development. It is anticipated that new challenges in hydrological modelling will arise and that there will be new requests and suggestions from users for additional functionality.

7 RECOMMENDATIONS

The long-term future of a software package such as SPATSIM-HDSF depends to a large extent on the interest of the user group and how frequently they use it. The earlier version of SPATSIM was used extensively by the IWR staff and students as well as a number of other users for some very specific purposes (notably Reserve determinations). This version was developed in a somewhat ad-hoc manner based on feedback from this group of users and their requirements for new facilities. For example, the drought indices analysis routines (part of the ‘Procedures’ section of the software) were added through a partnership with the International Water Management Institute (IWMI) and the IWR (Smakhtin and Hughes, 2007). The facility for generating annual and monthly summaries of time series data was added at the request of the CSIR. While both of these requests were responses to the specific needs of one organisation, the results were beneficial to all users of the software. It is therefore recommended that SPATSIM-HDSF should evolve in the future in the same way and this can be facilitated by maintaining the capacity to modify the code at the two existing centres (IWR and BEEH) as well as expanding this capacity to other groups if this is considered appropriate.

Experience at the IWR suggests that SPATSIM (the previous version) and SPATSIM-HDSF are potentially powerful tools for both research and practice. The software has certainly enhanced the research efficiency (in the field of hydrological modelling) of the IWR and several post-graduate students have relied heavily on the software for their data management and analyses. From a practical perspective, many of the data management and analysis tools, as well as many of the models included, have been designed for use in practical problem solving environments; Reserve determinations being one of the most obvious examples.

A software package such as SPATSIM-HDSF should never remain static and it should be continually developing to improve efficiency and extend the range of facilities. The structure of the software has been designed to allow this to happen without affecting existing users and their applications – this is considered to be one of the major strengths of the software. Ultimately, the long-term future and further developments of the software will depend on the number of users and how they respond through comments, criticisms and suggestions. It will also depend on the interest of potential funders to provide the financial resources to cover some of the costs of future developments. Some of these will inevitably take place without the need for further funding, particularly if the existing software development hosts

(IWR and BEEH) are using the software themselves (i.e. they will continue to develop the software to meet their own needs). However, as the user base increases so will the need for training and user support. The question is therefore how will these costs be recovered? There has been a great deal of interest in SPATSIM from groups outside South Africa and particularly in other developing countries who have difficulties with funding the costs of commercial software of a similar type. This interest has the potential to increase the size of the user group, but also stretches the resources of the development team in terms of providing support. The question is therefore whether or not we wish to 'market' the software outside South Africa and how we will service this 'market' in the future? The answers to these questions cannot be provided only by the development team and therefore one of the key recommendations of this report is the establishment of a SPATSIM-HDSF user group that is made up of the development team (BEEH and IWR), DWA, the WRC and other key users within South Africa. The purpose of this group would be to monitor the use of the software, make recommendations about future developments and potential sources of funding, identify training needs and how they should be addressed and generally be responsible for the long-term sustainability of the software. The group could interact mostly through e-mail contact, but an annual meeting that could include a wider group of existing and potential users is also recommended.

Many of the models that have currently been included as part of SPATSIM-HDSF are focussed on the analysis and simulation of water quantity, while water quality has largely been neglected. If SPATSIM-HDSF is to be considered as a system that supports the types of analyses required for integrated water resources management, it is important that water quality analysis methods are added in the future. There are many water quality models and modelling approaches available and some of these have been used within South Africa. It is therefore recommended that a future 'user group' investigate the possibility of including some water quality models or analysis methods.

Further improvements to the *ACRU* Configuration Editor could include:

- Functionality to enable all or specific components within an *ACRU* model input data file to be imported into other *ACRU* model input file, and to export a component to a new *ACRU* model input file.
- The manner in which projects are managed related to locations of input and output data and relative pathing.
- Modifications to deal better with large configurations.

There is a general requirement in the *ACRU* Configuration Editor for the development of data visualisation tools for both spatial and time series. Specifically, GIS related tools could include:

- Inclusion of the AAMG utility into the *ACRU 4* modelling system and modification of AAMG to write to the new *ACRU* XML model input files. AAMG is similar to the External GIS Tools in SPATSIM-HDSF but designed specifically for the setup of *ACRU* model variables through ArcGIS.
- Creation of data reader/writer and linkage classes for dBase files so that data stored in ESRI shape files can be referenced in *ACRU* model input files.
- Inclusion of GIS tools in the *ACRU* Configuration Editor for configuring Components and Relationships and for data visualisation.
- Development of tools to do statistical analyses on large sets of time series, and store the results of these analyses in a suitable format.

Recommended additions to the *ACRU* Menu Converter include:

- Functionality to specify how the subcatchments specified in an *ACRU* 3.00 or an *ACRU*2000 version model input data file are to be structured once converted. This functionality should enable users to specify whether subcatchments are to be converted as subcatchments or hydrological response units (HRU's) and how they are grouped into a hierarchy of subcatchments and catchments.
- The ability to specify reference climate files that are shared by multiple components. An example of this would be where all the HRU's within a subcatchment reference a single common reference climate.

Further improvements to the *ACRU* model could include:

- Optimisation of model code to improve performance.
- Possible use of compiled versions to improve performance.
- Investigation into how better compatibility with SPATSIM-HDSF can be achieved.

Further improvements to the *ACRU* model user manual could include:

- Descriptions of typical catchment configuration use cases especially for specialised spatial units such as Wetland and RiparianZone.

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APPENDICES

APPENDIX A

SPATSIM-HDSF: User Manual

SPATSIM-HDSF User Manual

Version 1.0
November 2011

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Some portions of this user manual have been based on the following documents:

- The final report (Clark et al., 2008) for a WRC Project K5/1490 titled:
  "Design And Development Of A Hydrological Decision Support Framework."
- Online SPATSIM Help files.

([http://www.ru.ac.za/static/institutes/iwr/software/reserve/helpdss/main_index.htm])

KEY

When this symbol appears in manual it indicates useful tips and information of the user.

Warnings and other important information are indicated by this symbol.

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1. BACKGROUND AND OVERVIEW OF SPATSIM-HDSF

SPATSIM-HDSF is a Hydrological Decision Support Framework (HDSF) within which integrated hydrological and related simulation modelling can take place. SPATSIM-HDSF facilitates linking and running models within a common graphical user interface containing appropriate Geographic Information System (GIS) and data analysis tools linked to a common database data model designed to store spatial and temporal data. The SPATSIM-HDSF framework is intended as an integrated modelling tool for use by water resources managers in assessing and managing water resources.

1.1 Background

As demand for water resources increases in South Africa it is necessary for water to be managed and utilised with greater efficiency. The management paradigm has changed from a focus on meeting demands from surface water supplies to a more holistic approach which also considers other aspects such as water quality, the environment as a water user, surface water-groundwater interactions, and social and economic impacts. This new management paradigm, known as Integrated Water Resources Management (IWRM), requires a greater understanding of complex hydrological systems. Since the 1980s advances in computer science combined with improved understanding of hydrological processes has resulted in the development of computer simulation models that encapsulate and aid understanding of hydrological systems. However, many of the models were developed for a particular domain within the hydrological system, such as surface water, groundwater or ecology, by experts in that domain. IWRM requires that the models for each domain be integrated and that scientific experts collaborate in a holistic assessment and management of water resources.

The need to integrate water resources models has led to the recognition of the need for and development of modelling frameworks. Traditionally models have each been run within their own modelling systems, each consisting of similar tools to prepare model input data, write model input files and analyse model output. Modelling frameworks seek to reduce duplication of effort and ease model use and development by providing common data preparation and post-processing tools, including a Geographic Information System (GIS) and database management, for use with several models.

1.2 Development History

The Spatial and Time Series Information Modelling (SPATSIM) was developed by the Institute for Water Research (IWR), Rhodes University, Grahamstown, and was first released in 1999. The design of SPATSIM was based on the approach adopted by the Centre for Ecology and Hydrology (CEH) at Wallingford, United Kingdom (Hughes, 2002). SPATSIM is described by IWR (2005) as an integrated hydrology and water resource information management and modelling system. SPATSIM integrates spatial and time series information in a flexible framework that includes a variety of data storage, retrieval, analysis and display options suitable for the application of a range of different models (Hughes, 2002). SPATSIM contains an extensible data model enabling storage of spatial and temporal data. Spatial data are stored in Environmental Software Research Institute (ESRI) shape files and a set of related Attributes stored in a Paradox-based relational database. The link between geographic data and Attribute data is achieved using four data dictionary tables stored in the database. The GIS functionality of SPATSIM includes vector-based GIS tools for visualisation and management of spatial input and output data. SPATSIM includes tools for the analysis and display of time series data. SPATSIM has been designed in an extensible manner such that new models may be easily added without changing SPATSIM. For a model to be run from SPATSIM, the model or the model user interface needs to be modified to read from and write to a SPATSIM database. The data model used in SPATSIM facilitates linking of models in series. The SPATSIM software was developed using the Delphi programming language. The SPATSIM software has been under continued development by the IWR.

In 2004 a project funded by the Water Research Commission (WRC Project K5/1490) was initiated. The primary objective of this project, as described in Clark *et al*. (2008), was the development of a Hydrological Decision Support Framework (HDSF) which can incorporate relevant and appropriate simulation models linked by a common flexible and extensible database and integrated with a GIS for use at a planning and operational level by Catchment Management Agencies (CMAs) at spatial scales ranging from point of use to the entire Water management Areas (WMA) and at temporal time scales of one day. The SPATSIM modelling framework described in Hughes (2002) and Hughes (2005) was selected to form the core of the HDSF as it was locally developed, included a generic extensible database structure for the storage of both spatial and time series data, included both GIS and data analysis tools and was suited to further development. The SPATSIM software was further developed to meet the requirements of the HDSF and this new version of the software is referred to as SPATSIM-HDSF. Some of the significant changes made to the SPATSIM software were:

- enhancements to the database data model,
- enhancements to the main user interface,
- enhancements to the internal GIS tools,
- change from Paradox to Microsoft Access database format,
- conversion of code to Delphi for .Net,
- development of new Attribute value editing forms compiled as a library,
- development of consolidated set of time series (TS) analysis tools compiled as a library,
- development of a set of database data access classes compiled as a library, and
- development of external GIS tools linking ArcGIS to SPATSIM-HDSF database.

1.3 Terminology

In order to understand the structure of SPATSIM-HDSF and how it works it is necessary to know some terminology used in this document in relation to SPATSIM-HDSF.

Feature: The term *Feature* in SPATSIM-HDSF refers to the GIS concept of a feature as being a collection of similar spatial elements sharing the same Attributes. For example, a catchments *Feature* is a collection of polygons representing the boundaries of a set of catchments. A group of non-spatial elements will also be referred to as a *Feature*. An example of a non-spatial Feature is a set of industrial water users, their exact spatial location is not known but their demand for water is important. In some instances a geo-referenced image may also be referred to as a *Feature*. An example of an image *Feature* is an image representing a topographical map of the catchment being modelled.

Object: An *Object* will refer to a unique element within a spatial or non-spatial *Feature*. For example, a catchments *Feature* may contain a catchment *Object*, identified as Umgeni. *Objects* have three characteristics: identity, state and behaviour.

Attribute: *Attributes* describe *Objects*. An *Object* has Attributes or properties that describe its physical characteristics, structure or state. All the *Objects* belonging to a common *Feature* will have the same set of *Attributes*, however, the value for the *Attribute* will differ from *Object* to *Object*. For example, the *Objects* in a catchments *Feature* may have an area *Attribute*, however, the area of each catchment *Object* will be different. The *Attributes* values of an *Object* may change with time and thus describe an *Object's* state.

Attribute Group: To facilitate the management of large sets of *Attributes*, SPATSIM-HDSF enables these *Attributes* to be grouped into sets referred to as *Attribute Groups*.

Relationship: No *Object* exists in isolation, thus behaviour describes the interactions or *Relationships* between *Objects*. For example, two catchments may have a streamflow relationship where one catchment is downstream of the other catchment.

Data Type: Different *Attributes* store different types of data or information, for example, single integer value, array of decimal values or a time series of values. In SPATSIM-HDSF there are eight different data types viz. Text, Integer, Real, Time Series, Picture, Array, Memo and Link, where:

- The Text data type stores alpha-numeric characters. Up to 256 characters can be stored.
- The Integer data type stores individual integer values. Each integer value is stored as a signed 32-bit integer.
- Real data type stores individual real numbers. Each real number is stored as a 32-bit floating point value.
- The Time Series data type stores a time series of real number values. The data storage for each time series real number value stored as a 32-bit floating point value. Each time series data point can have an associated data quality flag.
- The Picture data type enables the storage of pictures in a range of different image formats.
- The Array data type enables the storage of a two-dimensional matrix of real numbers. Each real number in the matrix is stored as a 32-bit floating point value.
- The Memo data type stores sets of alpha numeric characters that are too big for the Text data type.

- The Link data type enables the storage of links to data already stored in other Attributes, for the purpose of preventing the repetition of data in a SPATSIM-HDSF database, especially large time series datasets.

1.4 Structure of SPATSIM-HDSF

The conceptual components and data flows for SPATSIM-HDSF are shown in Figure 1.1. The SPATSIM-HDSF modelling framework consists of the SPATSIM-HDSF user interface, the SPATSIM-HDSF database data model, the SPATSIM-HDSF external GIS tools as a link to ArcGIS and a set of SPATSIM-HDSF compliant models.

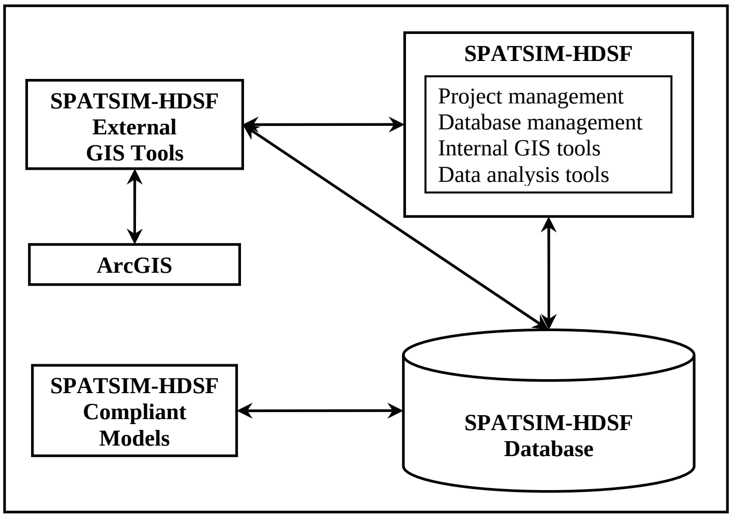


Figure 1.1 Conceptual components and data flows for SPATSIM-HDSF

The purpose of the SPATSIM-HDSF user interface is to provide a set of general modelling utilities including:

- Project management - Project management tools including setting up new project databases and archiving of projects.
- Database management - Database management tools to add, edit and delete data and information in a SPATSIM-HDSF database, tools to link model input and output variables to Feature Attributes in a SPATSIM-HDSF database and tools to import data into and export data from a SPATSIM-HDSF database.
- Internal GIS tools - A set of built-in GIS tools suited to setting up simple hydrological modelling inputs and providing a spatial view of model input and output parameters. These internal GIS tools are intended to provide a basic set of GIS tools enabling users to setup and run hydrological models without requiring expensive commercial GIS software. The internal GIS tools in SPATSIM-HDSF have been developed using Environmental Software Research Institute (ESRI) MapObjects GIS software development components and use ESRI shape files as the storage format for geographical data.
- Data analysis tools - A set of built-in time series data analysis tools including graphing and statistical analysis tools to enable a user to view, analyse and interpret model input and output time series parameters.

The SPATSIM-HDSF database data model enables the storage of spatial and temporal data and is extensible in that new hydrological modelling Attributes may be stored in the database without any change to the data model. The data model also enables storage of metadata, units of measure and relationships between components of the hydrological system being modelled.

The HDSF External GIS tools have been developed as an extension to ArcGIS and provides an important link between SPATSIM-HDSF and ArcGIS providing SPATSIM-HDSF users with access to the functionality built into a commercial GIS package for complex editing, analysis and manipulation of geographical data. The HDSF External GIS extension includes tools to:

- access and query information in a SPATSIM-HDSF database,
- select and load existing SPATSIM-HDSF projects, where the geographical data pertaining to the selected SPATSIM-HDSF project will be loaded into the ArcGIS environment and appropriate symbology and labelling will be applied to the GIS coverages,
- analyse gridded GIS information based on a specified SPATSIM-HDSF coverage so that Feature Attributes in a SPATSIM-HDSF database can be populated automatically, and
- area weight information in one coverage relative to a second coverage.

The current set of SPATSIM-HDSF compliant models includes:

- Desktop Parameter Calibration Model - This model reads information for all points in a Feature and checks to see if all the required data are available to define the type of Reserve determination that was carried out, the flow data that was used and the results of the determination. The model can then be used to display the results for a selection of sites against the default Desktop Reserve model parameter values. These can then be modified to better match the results of independent determinations.
- Desktop Reserve Model - This model is the widely used Desktop model for the ecological Reserve.
- Flow-Stressor Response Model - This model is used in the Reserve determination process (usually at intermediate and comprehensive levels).
- The Ground Water Version 3 Pitman Monthly Model - This version of the Pitman model, in terms of the generation of simulated natural flows, is equivalent to the new version of the standard Pitman model used in WR2005. However, in the simulation of development effects (reservoirs, abstractions, etc.) it uses a different approach.
- The Ground Water Version 3 Uncertainty Pitman Monthly Model – This is an uncertainty version of the Pitman model that includes the groundwater interaction components as developed by the IWR. The version allows for model parameters to be input as probability distributions rather than a set of single values. The model runs multiple times and generates ensemble outputs based on Monte Carlo random sampling from the parameter distributions.
- Pitman Model Parameter Exploration - This is the same version of the basic Pitman model but includes the input of range values and steps for selected parameters. The program then runs the model multiple times and generates objective functions (statistical comparisons between observed and simulated flows) for all the possible parameter combinations (using the specified step sizes within the specified range of parameter values). This model is used to

investigate parameter sensitivities and uncertainty associated with the Pitman model.

- The Real Time Reserve Management Model - The Real Time Reserve Management Model is described in Hughes *et al.* (2008).
- Reserve Licensing Model linked to the Desktop Model - A model to be used with the output from the Desktop Reserve model to assess present day and future (licence applications) water resource developments in relatively small catchments with respect to Reserve requirements.
- Satellite Daily Rainfall Capture Process - The Real Time Reserve Management Model is described in Hughes et al. (2008)
- *ACRU* Model - The *ACRU* agrohydrological model is a physical conceptual model that operates at a daily time step, it has been locally developed and applied in South Africa, but has also been applied in other countries.

1.5 Structure of Document

The purpose of this document is to serve as a user manual for the SPATSIM-HDSF modelling framework software and the models that run within it. Following on from the brief overview of SPATSIM-HDSF presented in this chapter, this remainder of this document includes four main sections:

- Chapter 2 introduces the main components of SPATSIM-HDSF;
- Chapter 3 provides detailed instructions on how to use SPATSIM-HDSF;
- Chapter 4 summarises the models supported in the framework; and,
- Chapter 5 contains information for model developers and provides details of the design of the SPATSIM-HDSF framework and associated software libraries that may be useful to model developers.

2. COMPONENTS OF SPATSIM-HDSF

The main components of SPATSIM-HDSF are the SPATSIM-HDSF User Interface, SPATSIM-HDSF Database and External GIS Tools. This chapter introduces these components of SPATSIM-HDSF in more detail.

2.1 Main SPATSIM-HDSF User Interface

The main window in the SPATSIM-HDSF user interface is organised as shown in Figure 2.1. The main window consists of a menu bar and tool bar at the top of the window, a navigation panel on the left-hand side of the window and a display panel on the right-hand side of the window. The display panel contains a *Map* tabbed page and a *Data* tabbed page.

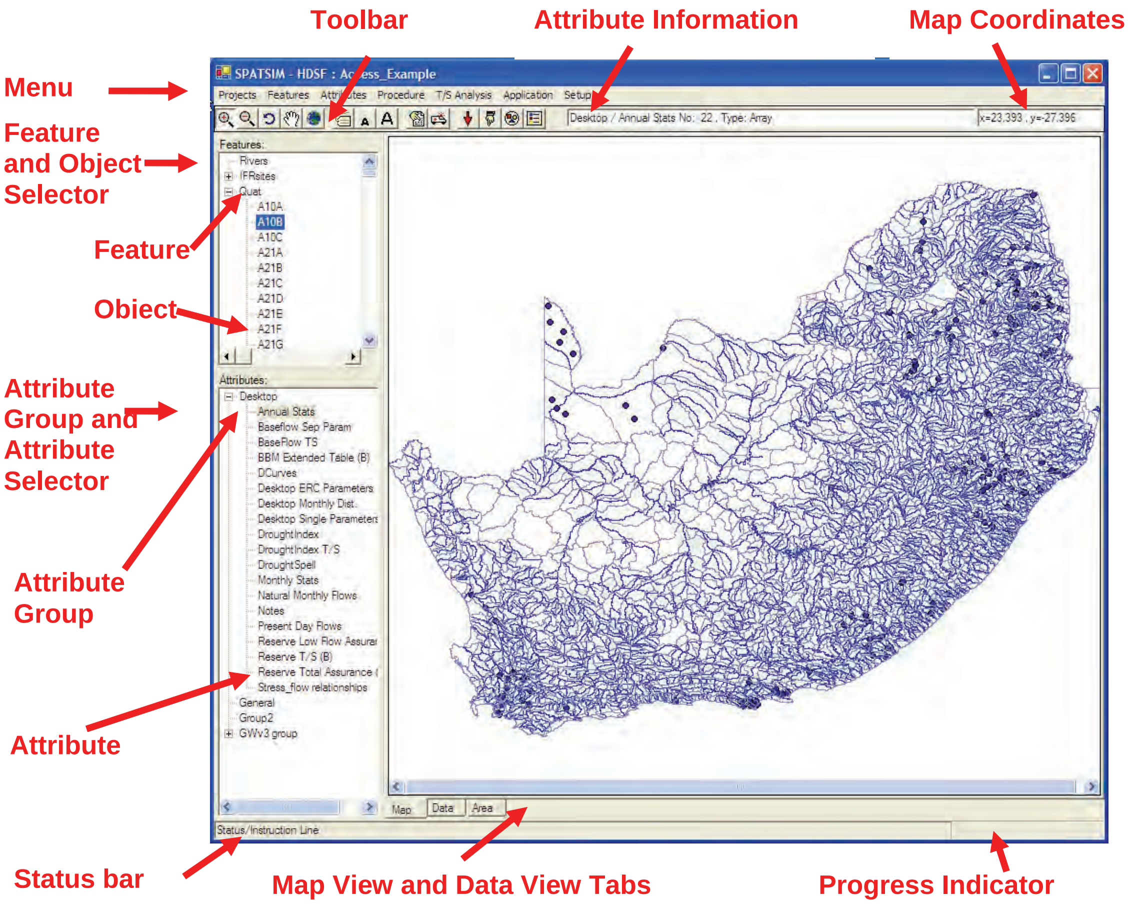


Figure 2.1 Layout of the main window in the SPATSIM-HDSF user interface

2.1.1 Navigation panel

The navigation panel is divided into two sections, the Feature and Object Selector at the top and the Attribute Group and Attribute Selector at the bottom. The Feature and Object Selector is a tree-view including a list of Features and all the Objects within a Feature. The Feature and Object Selector control is located at the top of the navigation panel on the left-hand side of the main window, as shown in Figure 2.1. Some examples of the Feature and Object Selector control are shown in Figure 2.2. The Feature and Object Selector control enables the user to select a Feature and to view and select a set of Objects within a selected Feature. In Figure 2.2 the example on the left-hand side shows three Features with the *Catchments* Feature selected. The example on the right-hand side of Figure 2.2 shows the *Catchments* Feature expanded to display a list of catchment Objects where catchment *V11A* has been selected. If a spatial Feature is selected and an Object in a spatial Feature is selected then the corresponding Object in the Map View flashes momentarily enabling users to easily locate the selected Object in the Map View.

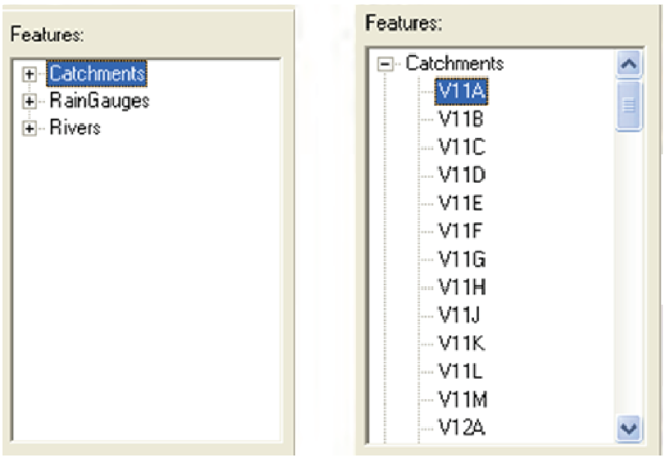


Figure 2.2 Examples of the Feature and Object Selector control

The Attribute Group and Attribute Selector is a tree-view displaying Attribute Groups and the Attributes contained within them. The Attribute Group and Attribute Selector is a tree-view displaying Attribute groups and the Attributes contained within them. The Attribute Group and Attribute Selector control is located at the bottom of the navigation panel on the left-hand side of the main window, as shown in Figure 2.1. Some examples of the Attribute Group and Attribute Selector control are shown in Figure 2.3. The Feature and Object Selector control displays a list of Attribute Groups in the first level of the tree structure and a list of the Attributes belonging to each Attribute Group in the second level of the tree structure. The tree structure of Attributes organised into Attribute Groups makes it easier for the user to locate an individual Attribute or sets of Attributes. By default an Attribute Group named *General* is created for each new spatial and non-spatial Feature. In Figure 2.3 the example on the left-hand side shows four Attribute Groups with the *General* Attribute Group selected. The example on the right-hand side of Figure 2.3 shows some of the Attribute Groups expanded and the *Area* Attribute in the *General* Attribute Group has been selected. The selection of an Attribute belonging to an Attribute Group will be used as part of many tasks that can be carried out within SPATSIM-HDSF, most importantly the task of entering or editing Attribute data, which is explained in more detail in Section 3.3.35. The addition of a new Attribute to a Feature is explained in more detail in Section 3.3.25.

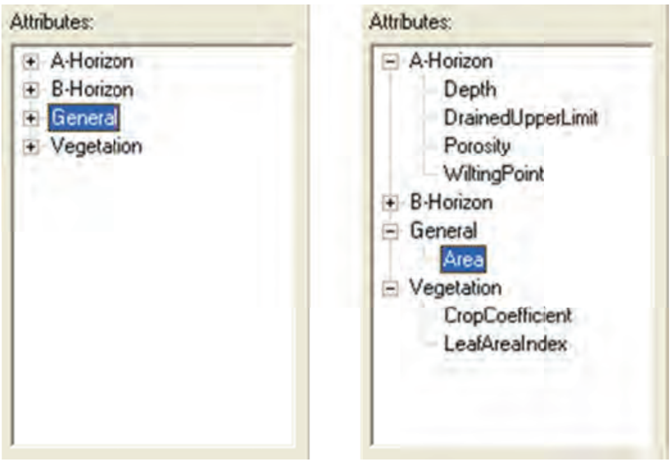


Figure 2.3 Examples of the Attribute Group and Attribute Selector control

2.1.2 Map tabbed page and internal GIS tools

The SPATSIM-HDSF user interface software contains a set of built-in GIS tools providing a spatial view of model input and output parameters. The spatial view is contained within the *Map* tabbed page. These internal GIS tools are intended to provide a basic set of GIS tools enabling users to setup and run hydrological models without requiring expensive commercial GIS software. The internal GIS tools in SPATSIM-HDSF have been developed using Environmental Software Research Institute (ESRI) MapObjects GIS software development components, and use ESRI shape files as the storage format for geographical data.

The internal GIS functionality currently provided in SPATSIM-HDSF includes the following:

- display spatial Features in the *Map* tabbed page;
- set up themes and display these in a legend;
- zoom-in, zoom-out, zoom-to-previous-extent, pan and zoom-to-full-extent tools;
- show, hide and resize Feature labels;
- rendering of Features as a theme using Attribute values; and
- selection of Feature objects on the map for use in other SPATSIM-HDSF tools and models.

Included in the internal GIS tools is the functionality to set up themes for a Feature, use of these themes for rendering based on Feature Attribute values and the display these themes in a legend display control. The main window of the SPATSIM-HDSF user interface, with the legend display control turned on, is shown in Figure 2.4.

The legend display button is used to toggle the legend display control on and off so that the map display area can be maximised when required. One or more themes may be set up for each spatial Feature in a SPATSIM-HDSF database. The setup information for each theme is stored in the SPATSIM-HDSF database using the *FeatureTheme* table. The setting of themes and use of the internal GIS tools are explained in Section 3.3.15.

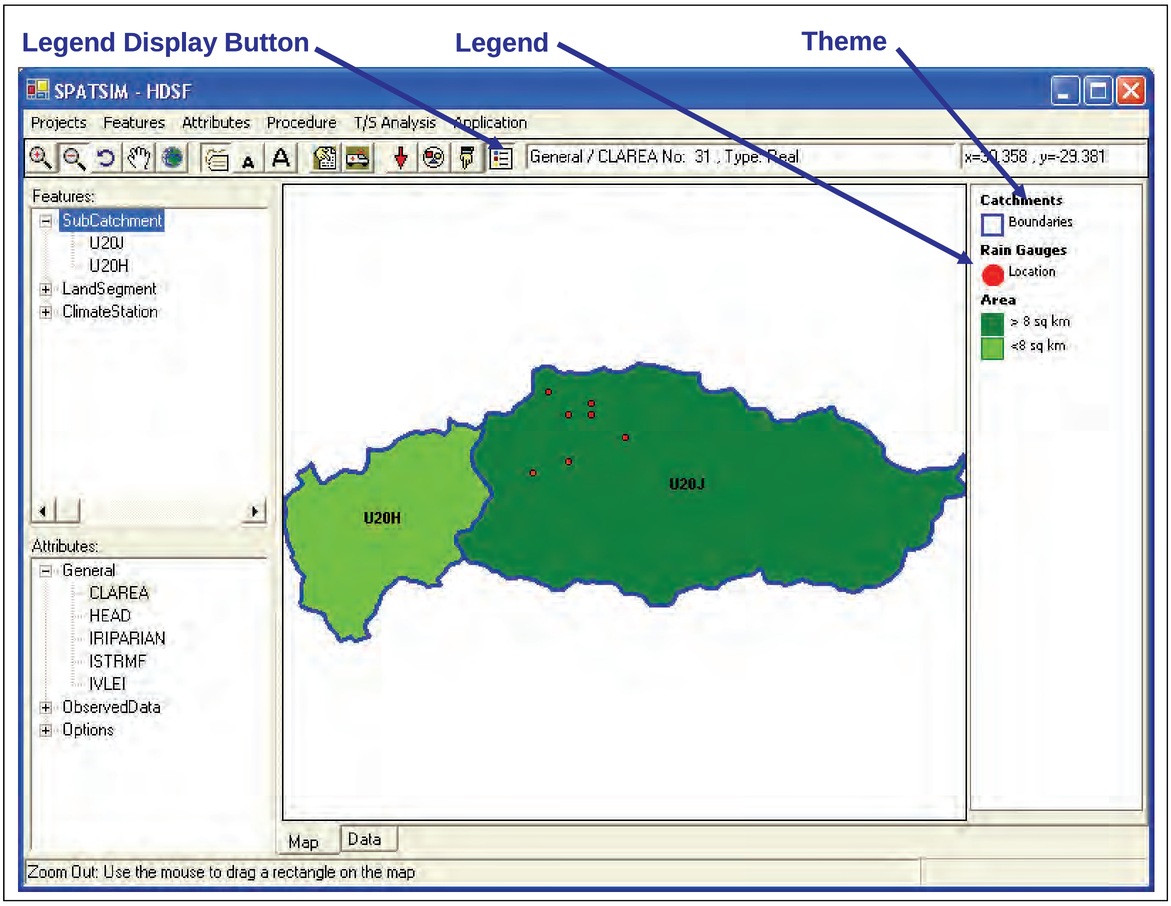


Figure 2.4 Main window in the SPATSIM-HDSF user interface with the legend displayed

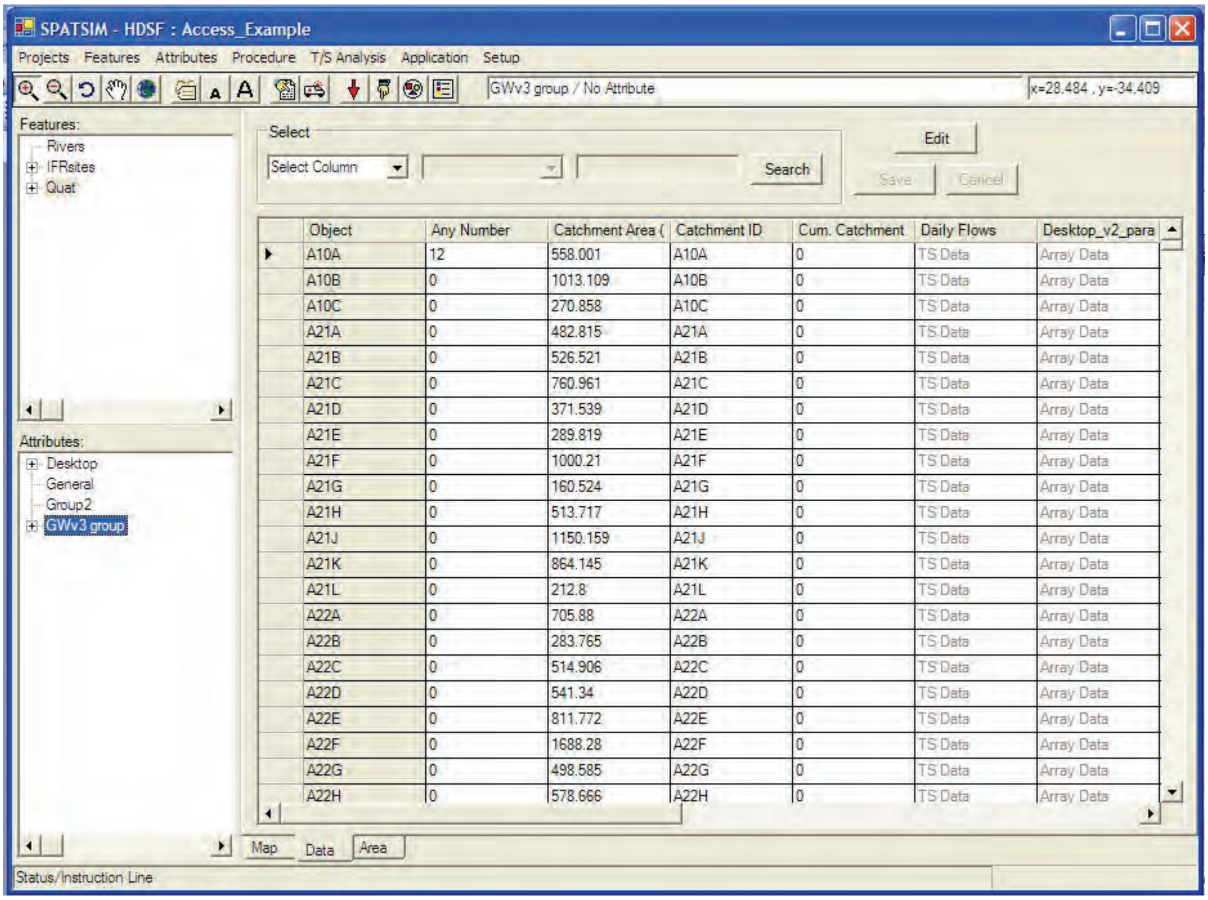
2.1.3 Data tabbed page

SPATSIM-HDSF is designed to be able to view, for a selected Feature and Attribute, the Attribute values for several objects at the same time in a data grid. The tabbed page labelled *Data* displays a data grid showing Attribute values for a selected Feature and Attribute Group as shown in Figure 2.5. This is particularly useful for non-spatial Features, for which there are no maps to display. If an image type Feature is selected then the *Data* tabbed page will be disabled.

The left-most column on the data tab page, named *Object*, displays a list of Object names. To the right of the *Object* column a set of columns is displayed, one for each Attribute in the selected Attribute Group. For the simple Attribute types *TextData*, *IntegerData* and *RealData* the data values will be displayed in the cells of the data grid. For the more complex Attribute types *TimeSeriesData*, *PictureData*, *ArrayData*, *MemoData* and *LinkData* the Attribute data type is displayed in the cells of the data grid.

The data grid is by default disabled for editing. If the user needs to edit an Attribute value then the *Edit* button should be clicked to make the data grid editable. Editing of data in a data grid is explained further in Section 3.3.35. Alternatively all Attribute data types may be edited by right-clicking with the mouse on a cell in the data grid and selecting *Edit* from the popup menu to open the appropriate Attribute data value editing window. These Attribute data value edit forms are described in more detail in Section 3.3.36.

The user may view general information about an Attribute displayed in the data grid by hovering the mouse over the header of an Attribute column in the data grid to display the tooltip text. By default the data grid is sorted first by the *Object* column in alphanumeric order. Using the mouse to right click on the header of an Attribute column in the data grid will display an Attribute popup menu. The *Sort Ascending* menu item enables the user to sort the rows in the data grid such that the values for the selected *TextData*, *IntegerData* or *RealData* type Attribute column are sorted in ascending order. The *Sort Descending* menu item enables the user to sort the rows in the data grid such that the values for the selected *TextData*, *IntegerData* or *RealData* type Attribute column are sorted in descending order.



Object	Any Number	Catchment Area (	Catchment ID	Cum. Catchment	Daily Flows	Desktop_v2_para
A10A	12	558.001	A10A	0	TS Data	Array Data
A10B	0	1013.109	A10B	0	TS Data	Array Data
A10C	0	270.858	A10C	0	TS Data	Array Data
A21A	0	482.815	A21A	0	TS Data	Array Data
A21B	0	526.521	A21B	0	TS Data	Array Data
A21C	0	760.961	A21C	0	TS Data	Array Data
A21D	0	371.539	A21D	0	TS Data	Array Data
A21E	0	289.819	A21E	0	TS Data	Array Data
A21F	0	1000.21	A21F	0	TS Data	Array Data
A21G	0	160.524	A21G	0	TS Data	Array Data
A21H	0	513.717	A21H	0	TS Data	Array Data
A21J	0	1150.159	A21J	0	TS Data	Array Data
A21K	0	864.145	A21K	0	TS Data	Array Data
A21L	0	212.8	A21L	0	TS Data	Array Data
A22A	0	705.88	A22A	0	TS Data	Array Data
A22B	0	283.765	A22B	0	TS Data	Array Data
A22C	0	514.906	A22C	0	TS Data	Array Data
A22D	0	541.34	A22D	0	TS Data	Array Data
A22E	0	811.772	A22E	0	TS Data	Array Data
A22F	0	1688.28	A22F	0	TS Data	Array Data
A22G	0	498.585	A22G	0	TS Data	Array Data
A22H	0	578.666	A22H	0	TS Data	Array Data

Figure 2.5 An example of the *Data* tabbed page

2.1.4 T/S Analysis tools

Time series analysis tools are included in SPATSIM-HDSF for analysis and display of model input and output time series data. Select *T/S Analysis* from the menu to view a sub menu that lists the time series analysis tools. This section provides a brief description of the time series analysis tools, further details on *T/S Analysis* can be found in TSAnalysis User Manual (Lutchminarain, 2010).

Graphs

The purpose of the *Time Series Analysis – Graphs* tool is to enable one or more sets of time series data to be plotted for visual analysis by the user. From the main menu select *T/S Analysis -> Graphs* which opens the *Time Series Analysis – Graphs* window. An example of the *Time Series Analysis – Graphs* window is shown in Figure 2.6 . The window contains two sets of graph axes separated by an adjustable splitter. On each set of graph axes one or more time series may be plotted as either line or bar graphs and a legend is created. On each set of graph axes a graph title and a y-axis title may be set. For each time series the colour of the line or bars may be set. Each set of graph axes includes controls to zoom and scroll to selected portions of a time series.

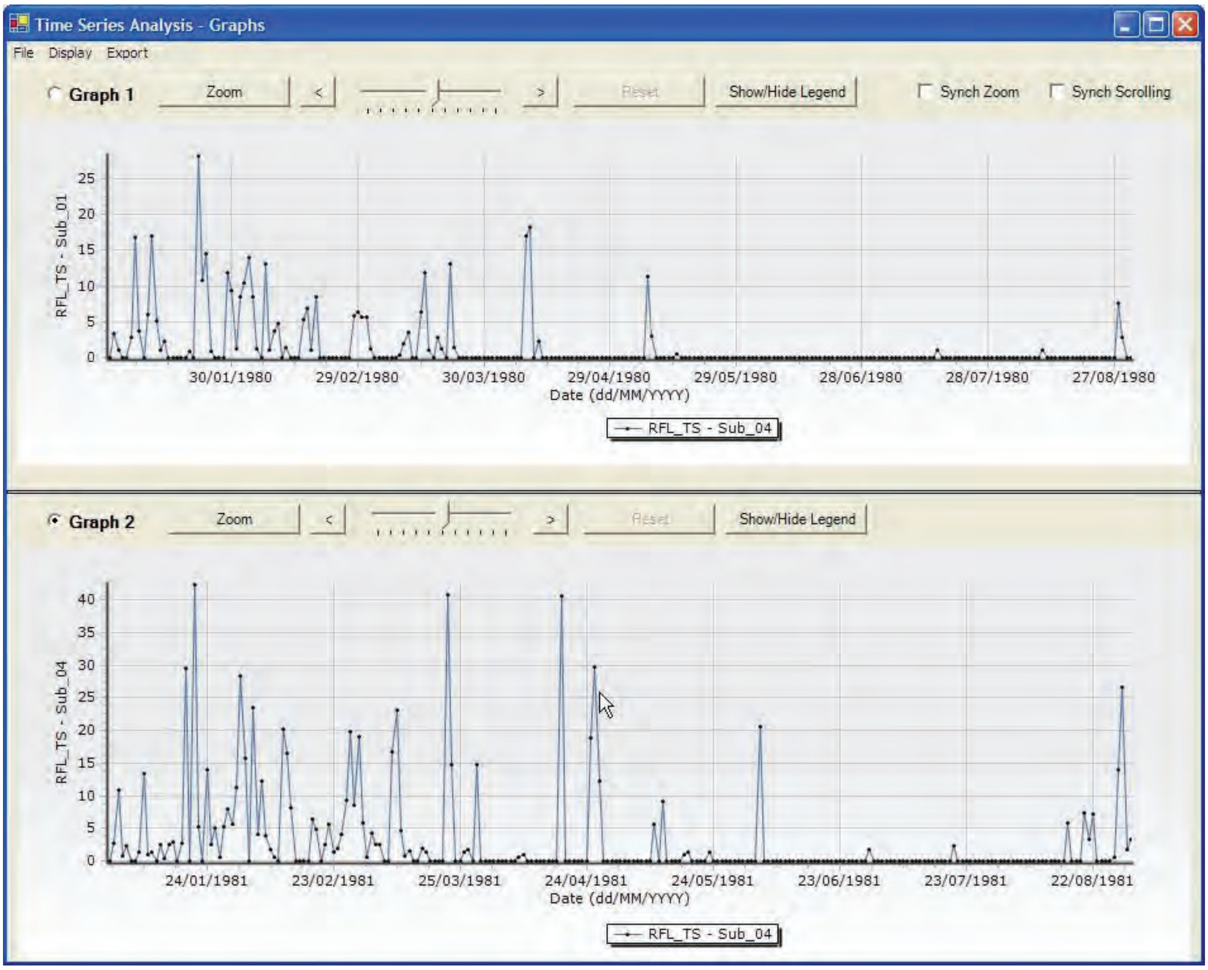


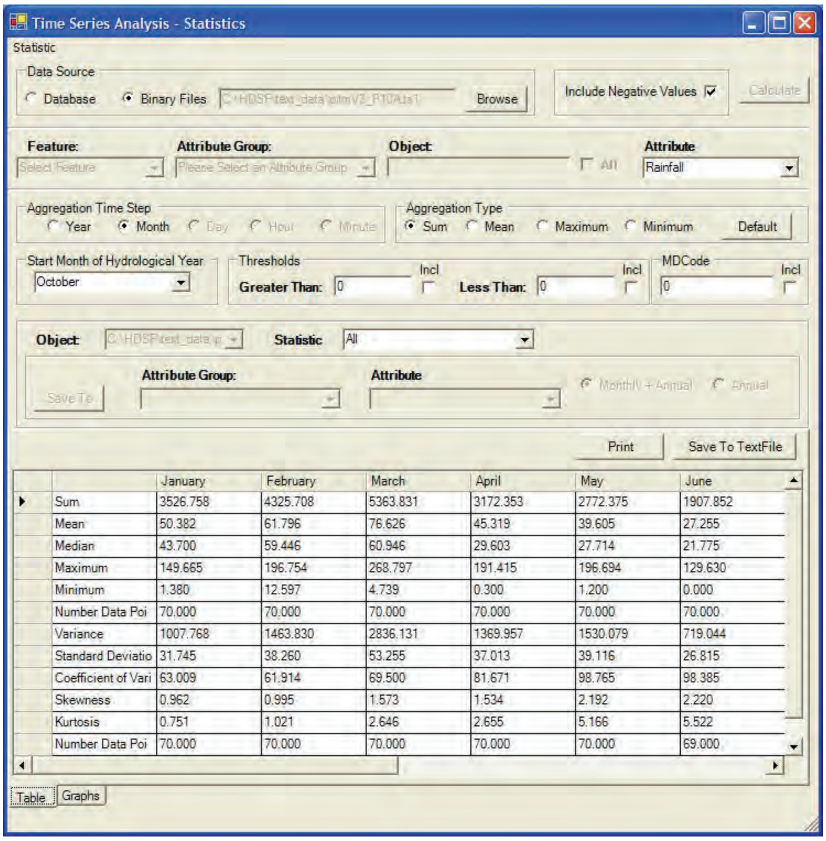
Figure 2.6 Example of the *T/S Analysis – Graphs* window

Statistics

The purpose of the *Time Series Analysis – Statistics* tool is to enable a set of useful month-by-month and annual statistics for a selected time series to be calculated, graphed and saved. From the main menu select *T/S Analysis -> Statistics* which opens the *Time Series Analysis – Statistics* window. An example of the *Time Series Analysis – Statistics* window is shown in Figure 2.7 and Figure 2.8. The following statistics are calculated:

- sum,
- mean,

- median,
- maximum,
- minimum,
- number of data points,
- variance,
- standard deviation,
- coefficient of variation,
- skewness,
- kurtosis,
- number of values less than a user specified threshold value, and
- number of values greater or equal to a user specified threshold value.



	January	February	March	April	May	June
Sum	3526.758	4325.708	5363.831	3172.353	2772.375	1907.852
Mean	50.382	61.796	76.626	45.319	39.605	27.255
Median	43.700	59.446	60.946	29.603	27.714	21.775
Maximum	149.665	196.754	268.797	191.415	196.694	129.630
Minimum	1.380	12.597	4.739	0.300	1.200	0.000
Number Data Poi	70.000	70.000	70.000	70.000	70.000	70.000
Variance	1007.768	1463.830	2836.131	1369.957	1530.079	719.044
Standard Deviatio	31.745	38.260	53.255	37.013	39.116	26.815
Coefficient of Vari	63.009	61.914	69.500	81.671	98.765	98.385
Skewness	0.962	0.995	1.573	1.534	2.192	2.220
Kurtosis	0.751	1.021	2.646	2.655	5.166	5.522
Number Data Poi	70.000	70.000	70.000	70.000	70.000	69.000

Figure 2.7 Example of the *Time Series Analysis – Statistics* window

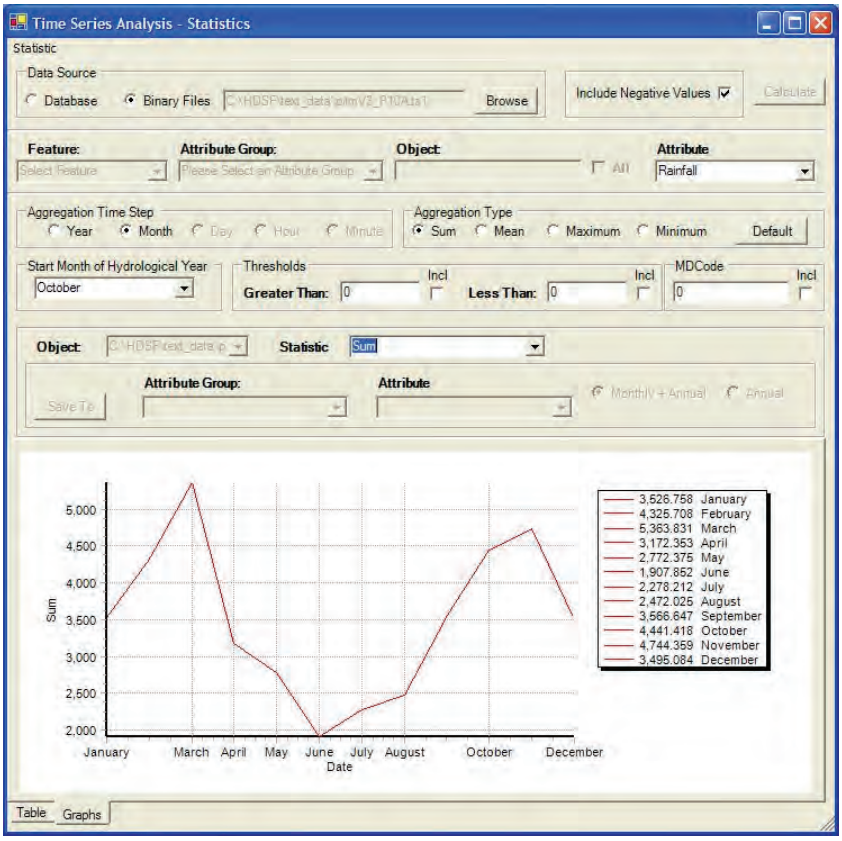


Figure 2.8 Example of the *Graphs* tab on the *Time Series Analysis – Statistics* window

Comparative Statistics

The purpose of the *Time Series Analysis – Comparative Statistics* tool is to enable the calculation of conservation and regression statistics between two time series, typically time series of observed and simulated data, and to create a scatter plot of the data in these two time series. From the main menu select *T/S Analysis -> Comparative Statistics* which opens the *Time Series Analysis – Comparative Statistics* window. An example of the *Time Series Analysis – Comparative Statistics* window is shown in Figure 2.9, Figure 2.10 and Figure 2.11. The following conservation statistics are calculated:

- sum (Attribute A and Attribute B),
- average error,
- mean (Attribute A and Attribute B),
- percentage difference between means,
- t statistic for comparing means,
- variance (Attribute A and Attribute B),
- percentage difference between variances,
- standard deviation (Attribute A and Attribute B),
- percentage difference between standard deviations,
- standard error (Attribute A and Attribute B),
- percentage difference between standard errors,
- total root mean square error (RMSE),
- coefficient of variation (Attribute A and Attribute B),
- percentage difference between coefficients of variation,
- skewness coefficient (Attribute A and Attribute B),

- percentage difference between skewness coefficients
- kurtosis coefficient (Attribute A and Attribute B),
- percentage difference between kurtosis coefficients, and
- t statistic for correlation testing.

The following regression statistics are calculated:
- correlation coefficient (Pearson's r),
- regression coefficient (slope),
- regression intercept,
- total sum of squares (SST),
- sum of squares due to regression (SSR),
- residual sum of squares (SSE),
- computer rounding error (SST - (SSR + SSE)),
- coefficient of determination (R^2),
- coefficient of efficiency, and
- coefficient of agreement.

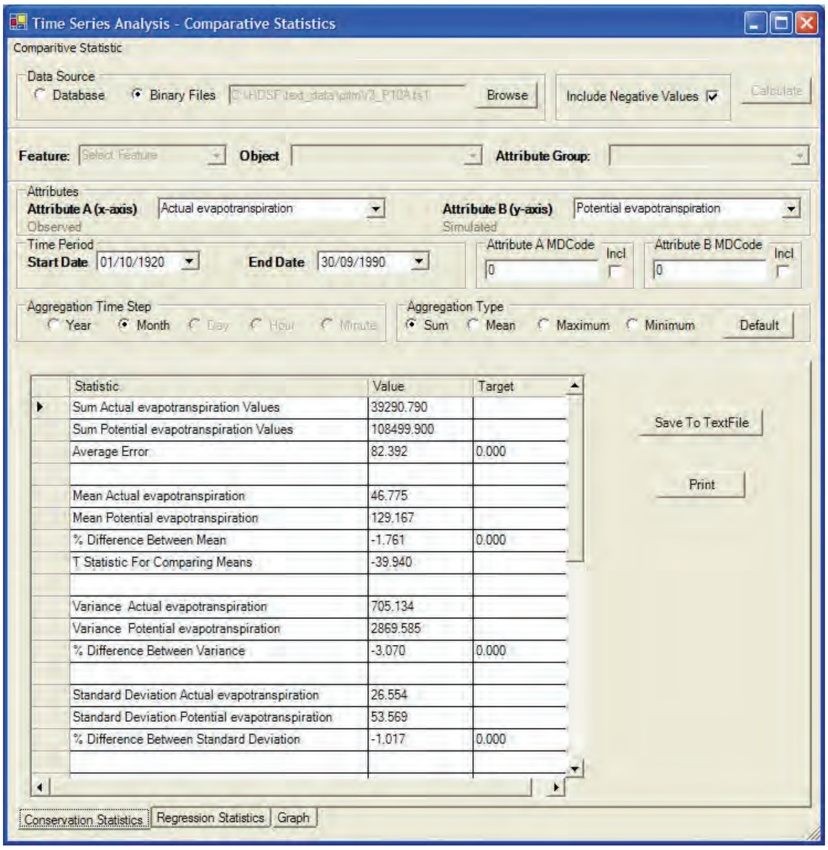


Figure 2.9 Example of the *Time Series Analysis – Comparative Statistics* window

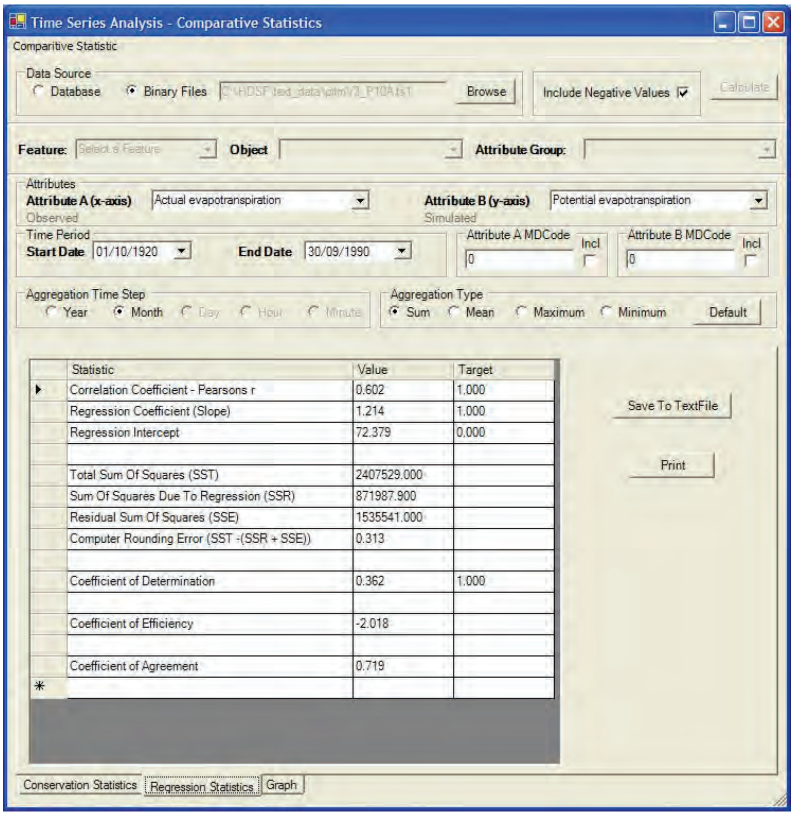


Figure 2.10 Example of the *Regression Statistics* tab on the *Time Series Analysis – Comparative Statistics* window

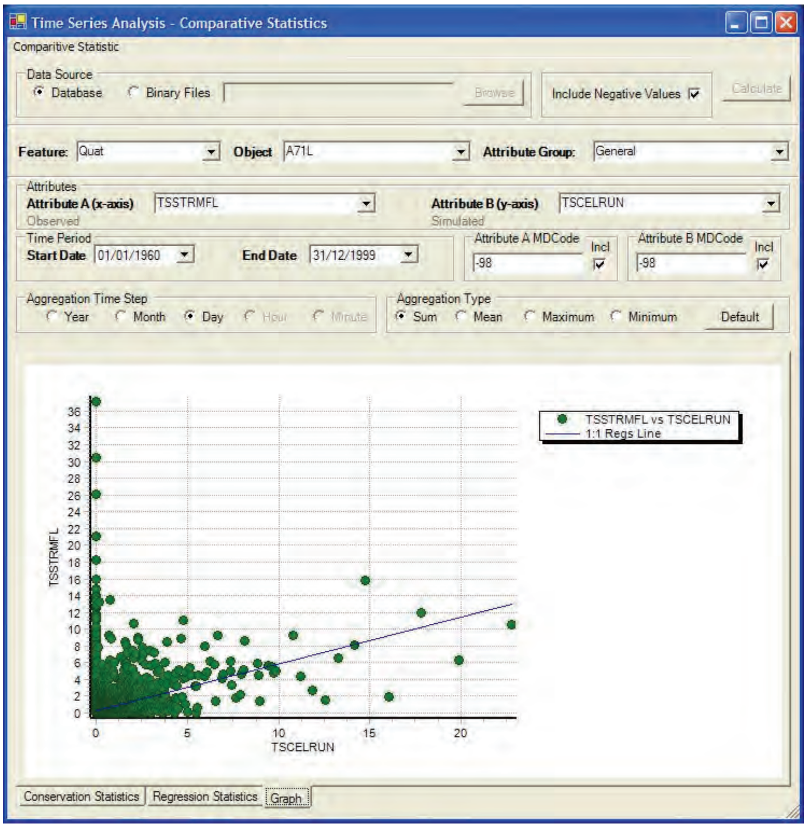


Figure 2.11 Example of the *Scatter Plot* tab on the *Time Series Analysis – Comparative Statistics* window

Frequency Analysis

The purpose of the *Time Series Analysis – Frequency Analysis* tool is to enable monthly, partial and annual frequency analyses to be performed on a selected time series and the results displayed as a table of values or a set of graphs. From the main menu select *T/S Analysis -> Frequency Analysis* which opens the *Time Series Analysis – Frequency Analysis* window. An example of the *T/S Analysis – Frequency Analysis* window is shown in Figure 2.12 and Figure 2.13.

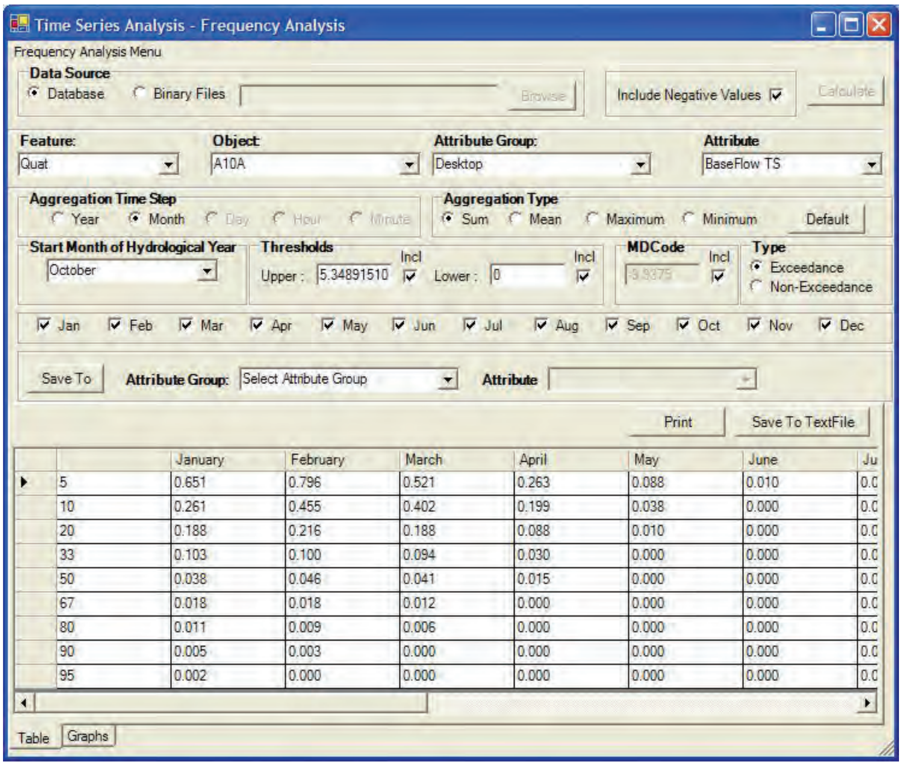


Figure 2.12 Example of the *Time Series Analysis – Frequency Analysis* window

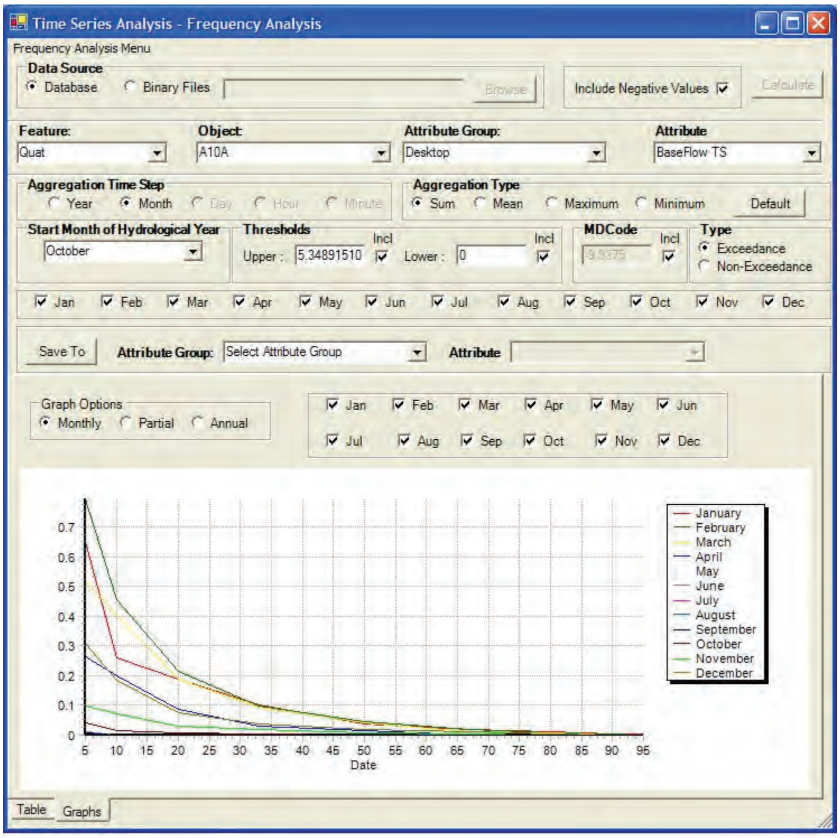


Figure 2.13 Example of the *Graphs* tab on the *Time Series Analysis – Frequency Analysis* window

Extreme Value Distributions

The *Time Series Analysis – Extreme Value Distributions* tool calculates the annual maximum series of a time series Attribute. The annual maximum series is then used to work out the Normal, Log-Normal, Gumbel and Log-Pearson Type 3 distributions. From the main menu select *T/S Analysis -> Extreme Value Distribution* which opens the *Time Series Analysis – Extreme Value Distributions* window. An example of the *Time Series Analysis – Extreme Value Distributions* window is shown in Figure 2.14. This window consists of two main sections, the time series selection and options panel at the top, and the extreme value distribution analysis results at the bottom. The results section contains *Annual Maximum Series*, *Statistics*, *Log Normal Distributions*, *Normal Distributions*, *Gumbel Distributions*, *Log Pearson 3 Distributions*, and *Graph* tabbed pages.

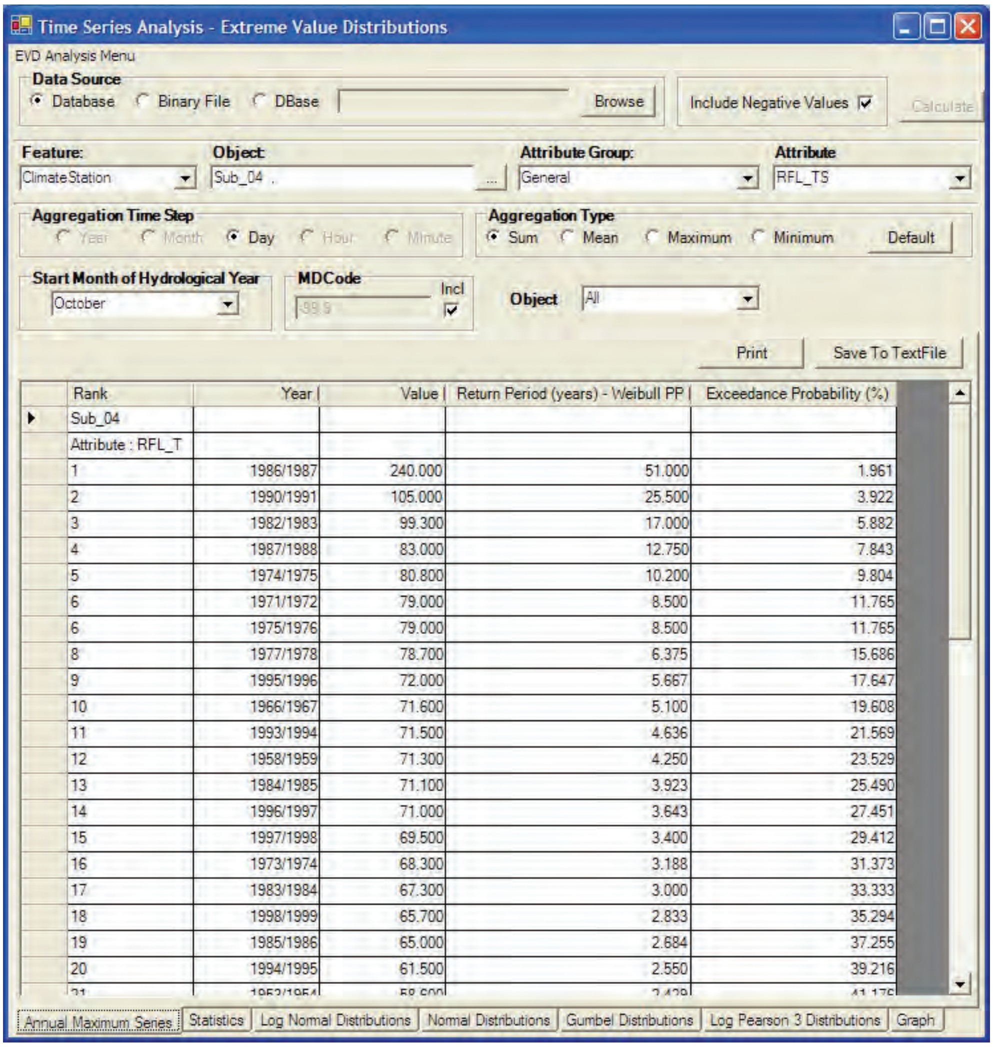


Figure 2.14 Example of the *Time Series Analysis - Extreme Value Distributions* analysis window

Run Length Analysis

The *Time Series Analysis – Run Length Analysis* tool calculates the lengths of consecutive days, a time series data set is above a threshold value and below a threshold value. In this tool 1 - 6 threshold values can be used. From the main menu select *T/S Analysis -> Run Length Analysis* which opens the *Time Series Analysis – Run Length Analysis* window. An example of the *Time Series Analysis – Run Length Analysis* window is shown in Figure 2.15. This window consists of two main sections, the time series selection and options panel at the top, and the run length analysis results at the bottom. The results section contains a *Graph* tabbed page which displays the results of the analysis graphically.

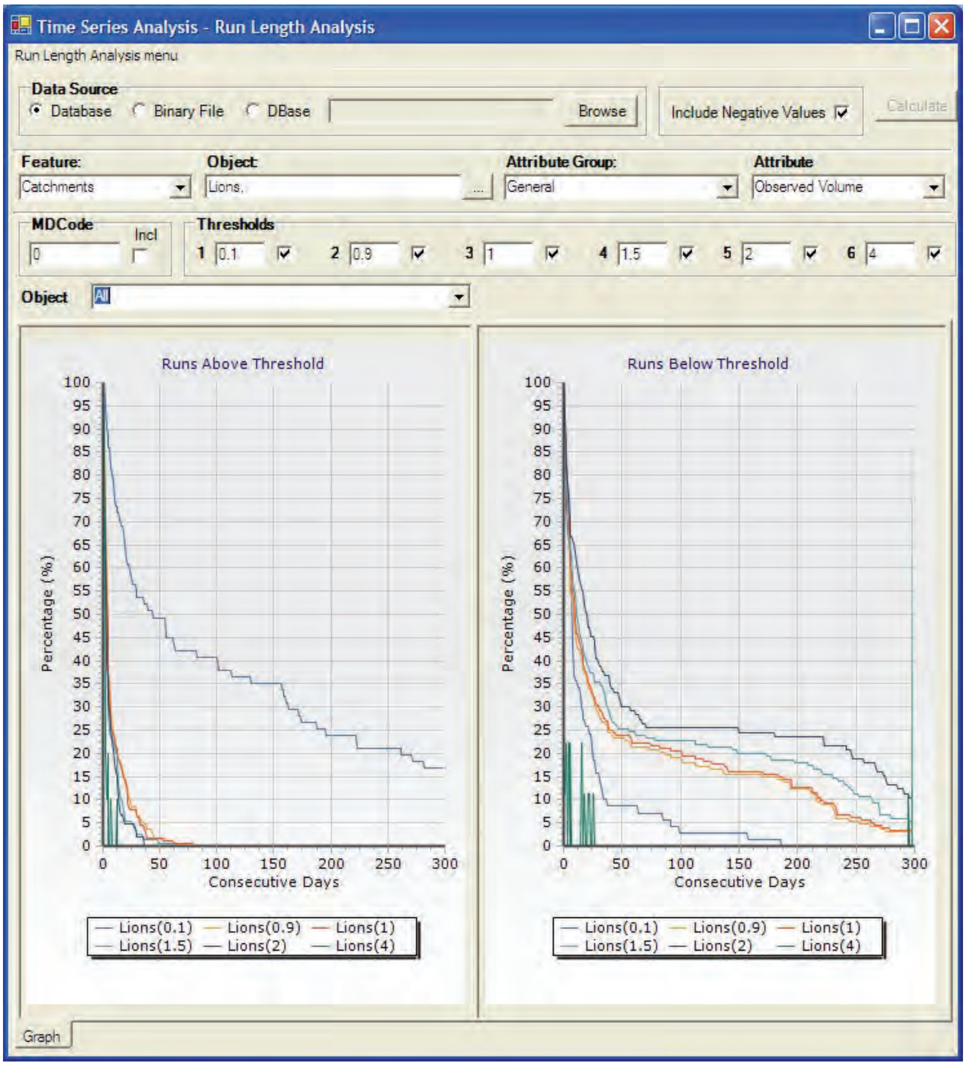


Figure 2.15 Example of the *Time Series Analysis - Run Length Analysis* window

High/Low Period Analysis

The *Time Series Analysis – High/Low Period* tool searches through a time series and finds the time period with the highest or lowest mean value for the given time period length. From the main menu select *T/S Analysis -> High/Low Period* which opens the *Time Series Analysis – High/Low Period* window. An example of the *High/Low Period* window is shown in Figure 2.16. This window consists of two main sections, the time series selection and options panel at the top, and the high/low period results in the *Data* tabbed page at the bottom.

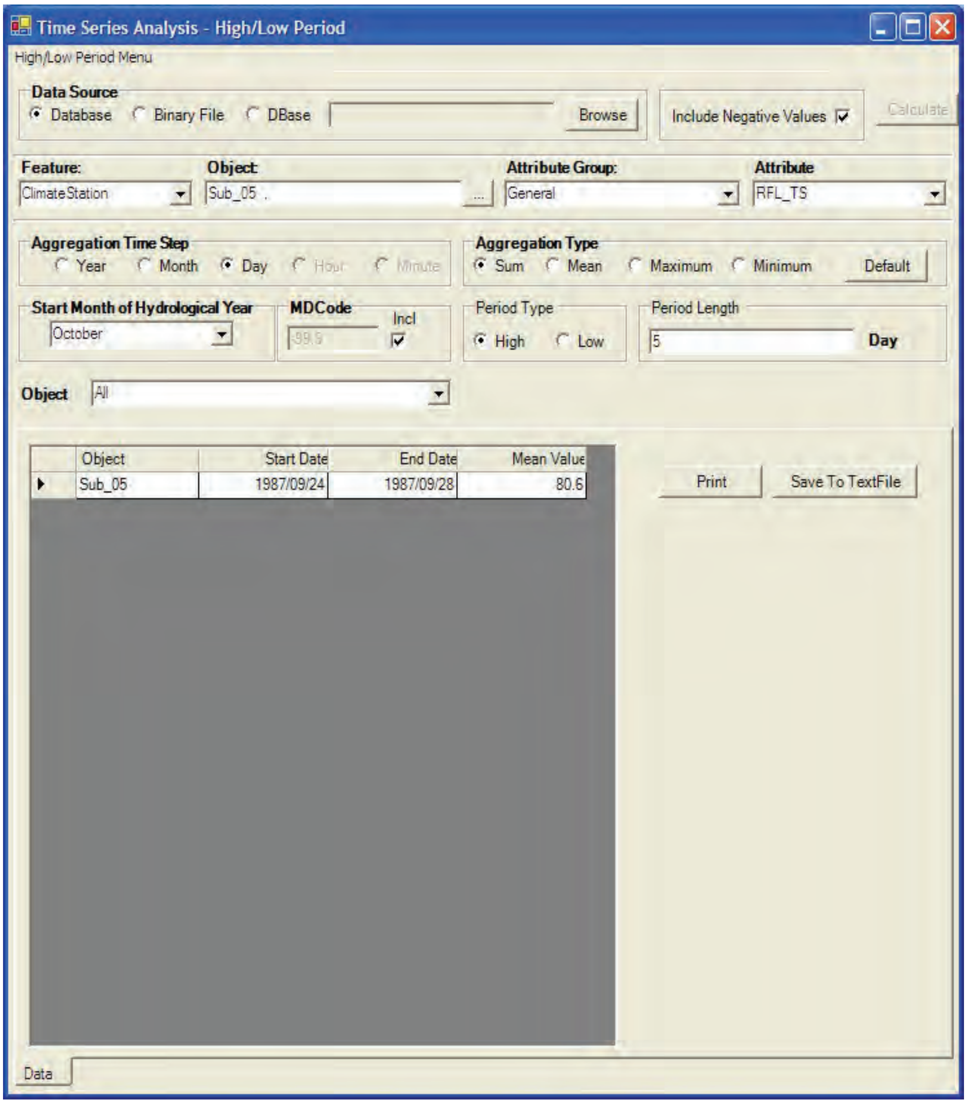


Figure 2.16 Example of the *Time Series Analysis - High/Low Period* Analysis window

Transformations

The *Time Series Analysis – Transformation* tool transforms time series values for one or more objects in a Feature. Transformations are used to apply corrections to time series, or to perform calculations on time series that result in a corresponding new time series of values. From the main menu select *T/S Analysis -> Transformation* which opens the *Time Series Analysis – Transformation* window. Only time series Attributes in a SPATSIM-HDSF database data source may be transformed. The *Time Series Analysis – Transformation* window consists of two tabbed pages. The first tabbed page is the *General* tab page, shown in Figure 2.17, which contains the following transformations:

- *Accumulate TS*: creates an accumulated time series (TS) from the original time series data set.
- *Accumulate X TS*: creates an accumulated time series according to a period length.
- TS * Y: creat*es a transform*ed time series where the values from the original time series data are multiplied by Y.

- *TS / Y*: creates a transformed time series where the values from the original time series data set are divided by Y.
- *TS1 + TS2*: creates a transformed time series which is the addition of two time series data sets, TS1 and TS2.
- *TS1 - TS2*: creates a transformed time series which is the difference of two time series data sets, TS1 and TS2.
- *TS1 – Median TS2*: creates a transformed time series which is the difference between a time series data set, TS1 and the median of time series data set, TS2.
- *TS1 – Mean TS2*: creates a transformed time series which is the difference between a time series data set, TS1 and the mean of time series data set, TS2.

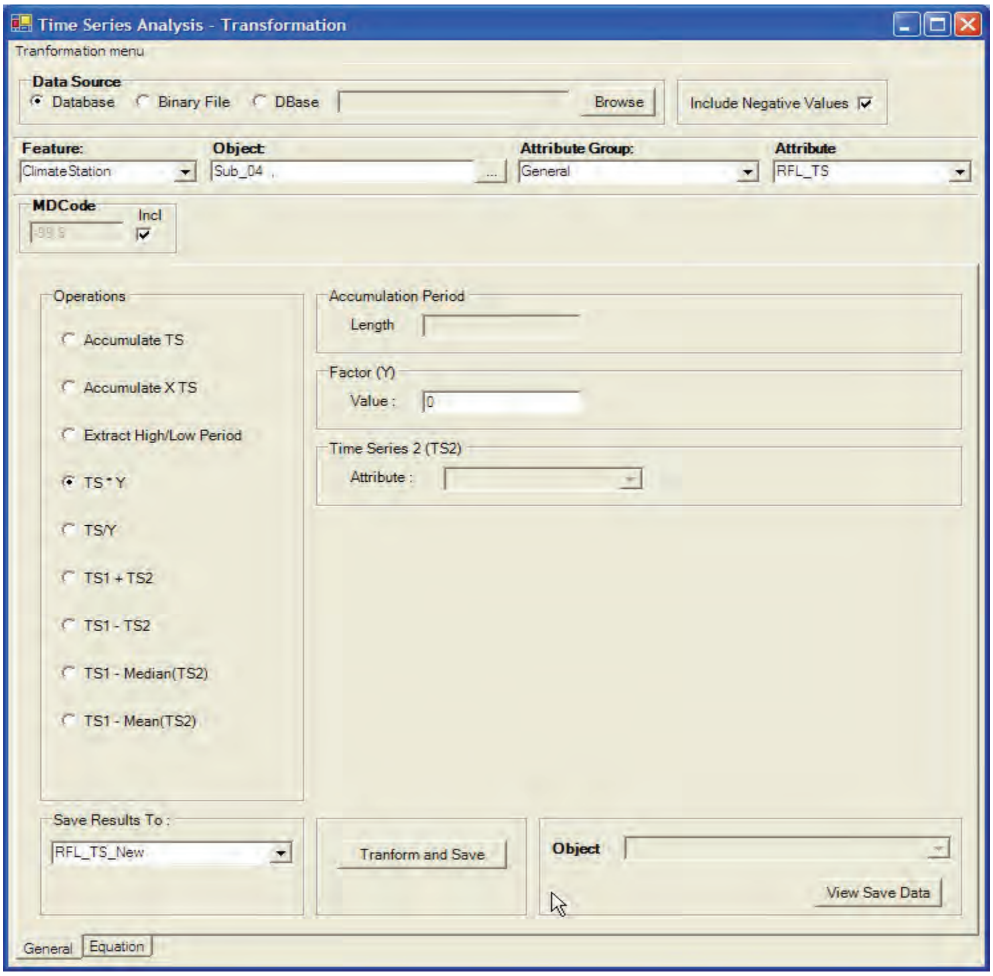


Figure 2.17 Example of the *Time Series Analysis - Transformation* window with the *General* tabbed page selected

The second tabbed page is the *Equation* tabbed page, shown in Figure 2.18, which enables the transformation of a dataset according to an equation. There are two equations, $y = Ax^2 + Bx + C$, and $y = Ax^B + C$, where y is the transformed value, x are the values from the time series dataset, and the values of A, B and C are coefficients set by the user.

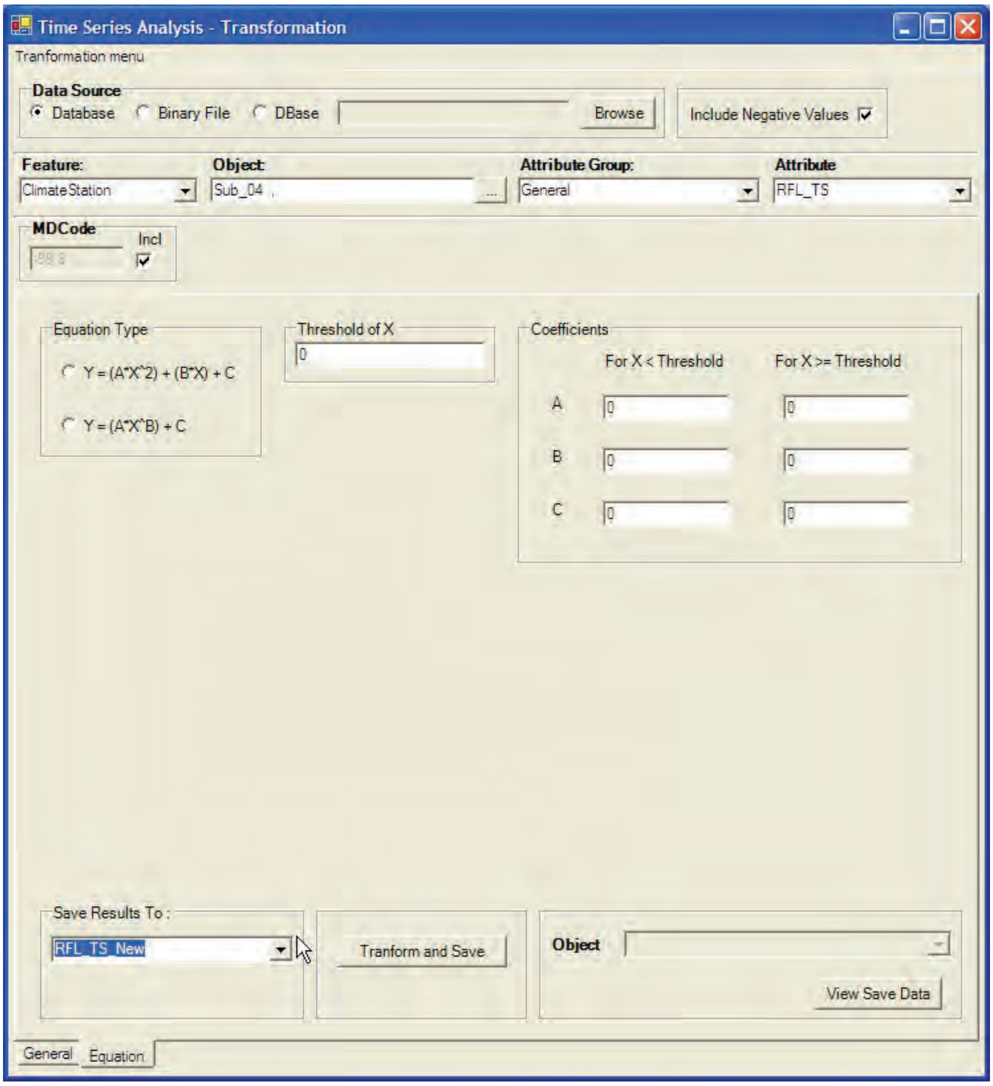


Figure 2.18 Example of the *Time Series Analysis - Transformation* window with the *Equation* tabbed page selected

2.1.5 TSGraph time series analysis tools

A generalised time series graph display and analysis software package named TSOFT was provided with SPATSIM. An updated version of TSOFT named TSGraph has been packaged with SPATSIM-HDSF.

TSGraph is designed to work with data reference files called Profile files (.prf) and these can contain references to records in a database table (such as a SPATSIM-HDSF time series Attribute table) or to SPATSIM-HDSF binary output files.

TSGraph can be run as a standalone application by clicking on the executable file (tsGraph.exe) which should be located in the same directory as the SPATSIM-HDSF (C:\HDSF\bin\Spatsim_HDSF.exe) or run directly from the SPATSIM-HDSF user interface as explained in more detail in Section 3.3.41.

The following tasks and procedures can be carried out by TSGraph:

- Plot data on graphs
- Calculate Monthly Distributions
- Calculate Duration Curves
- XY Plots
- Baseflow Analysis
- Run Analysis
- Transformation.

2.2 SPATSIM-HDSF Database

The SPATSIM-HDSF database data model enables the storage of spatial and temporal data and is extensible in that new hydrological modelling Attributes may be stored in the database without any change to the data model. The data model enables storage of metadata, units of measure and relationships between components of the hydrological system being modelled. SPATSIM-HDSF uses the SPATSIM-HDSF database data model to create a new database for each project that is created, thus if for example you have three SPATSIM-HDSF projects you will have three different SPATSIM-HDSF databases, one for each project.

SPATSIM-HDSF databases are implemented in Microsoft Access. The SPATSIM-HDSF database data model includes the following characteristics:

- extensible – adding new models and model variables does not require changes to the data model;
- generic – it is suitable for application with a wide range of hydrology related models;
- object oriented – it stores data in a manner suited to application with object oriented models;
- enables spatial and non-spatial components of the hydrological system to be represented;
- stores global model variables not related to components of the hydrological system;
- stores relationships between objects representing components of hydrological system;
- enables storage of metadata about Features, Attributes and individual Attribute values; and
- stores units of measure for all relevant data types.

2.3 External GIS Tools

Geographic Information Systems have become invaluable in hydrological modelling and GIS tools are an important component of the HDSF. The internal GIS tools in SPATSIM-HDSF are suitable for visualisation of spatial data and simple editing of geographical data in a SPATSIM-HDSF project. However, for complex editing or large scale geographical data manipulation the external GIS component of the HDSF enables users to utilize the functionality built into a commercial GIS package to display, edit and manipulate geographical information associated with a SPATSIM-

HDSF project. The external GIS tools have been developed as an extension to the ArcGIS desktop software using the Visual Basic .Net (Version 2.0) programming language. The HDSF External GIS extension includes:

- a toolbar with menu and button options,
- forms to catch and display error messages which may arise during the execution of the code,
- database connection classes to access and query information in a SPATSIM-HDSF database,
- selection and loading of existing SPATSIM-HDSF projects, where the geographical data pertaining to the selected SPATSIM-HDSF project will be loaded into the ArcGIS environment and appropriate symbology and labelling will be applied to the GIS coverages,
- analysis of Gridded GIS information based on a specified SPATSIM-HDSF coverage so that Feature Attributes in a SPATSIM-HDSF database can be populated automatically, and
- area weighting of information in one coverage relative to a second coverage.

The HDSF External GIS tools toolbar for ArcGIS is shown in
Figure 2.19. Using this toolbar the user may select a SPATSIM-HDSF database, view spatial data from a SPATSIM-HDSF database and perform GRID and area weighting analyses.

Figure 2.19 SPATSIM-*HDSF* external GIS tools toolbar for ArcGIS

An example of the use of the External GIS tools to display Attribute data for a spatial Feature stored in a SPATSIM-HDSF database is shown in Figure 2.20. In Figure 2.20 it is shown, how using the HDSF External GIS toolbar in ArcGIS, a connection to a SPATSIM-HDSF database has been created, and values of mean annual precipitation (MAP) for a Feature containing quaternary catchments, have been loaded into ArcGIS and displayed. A predefined legend has been used and the quaternary catchments have been automatically labelled using one of the fields in the shape file as specified in the layer (*.lyr*) file associated with the shape file. Once data has been loaded from a SPATSIM-HDSF database all ArcGIS functionality is available including the creation of layouts for printing.

Using the GRID analysis tool, which is part of the SPATSIM-HDSF External GIS tools, data can be extracted from GRIDs by selecting a SPATSIM-HDSF spatial Feature and Attribute and specifying an associated GRID from which to extract the data. The extracted data values are then saved in the SPATSIM-HDSF database for the selected Attribute. An example of the use of the GRID analysis setup window is shown in Figure 2.21. In the example shown, all the catchment values for MAP are populated with the average MAP derived from the GRID named ‘mean_an_precip’.

Using the coverage area weighting analysis tool, which is part of the SPATSIM-HDSF External GIS tools, spatial data can be area weighted by selecting a SPATSIM-HDSF spatial Feature and Attribute and specifying a coverage containing data to be area weighted and the data field to be area weighted. The area weighted data values are then saved in the SPATSIM-HDSF database for the selected Attribute. An example of the use of the coverage area weighting analysis setup window is shown in Figure 2.22. In the example shown, the crop coefficients for January are area weighted per catchment and saved to the specified Attribute in the SPATSIM-HDSF database.

For detailed descriptions of how to install and use the HDSF External GIS tools refer to the manual titled "*External GIS Tools For The Hydrological Decision Support Framework*" (Meier *et al*. 2008).

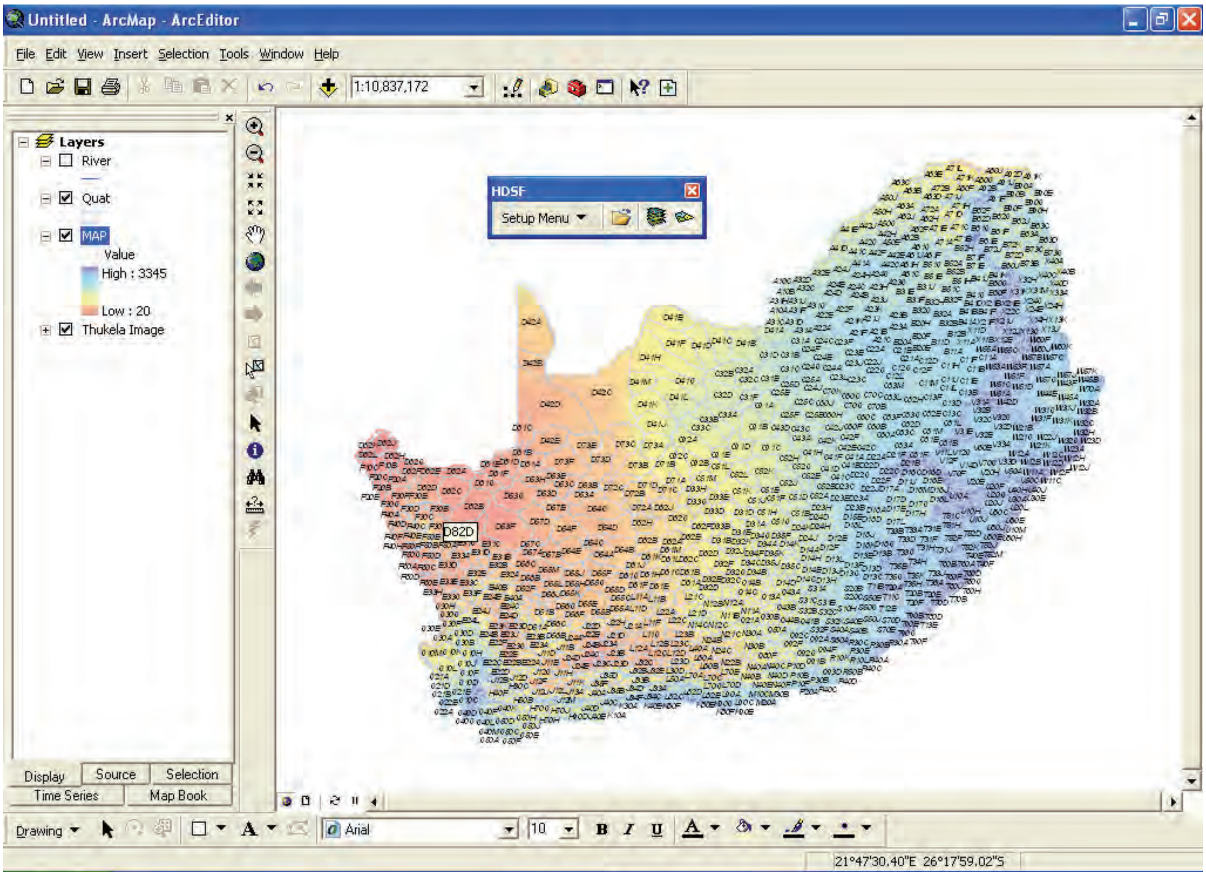


Figure 2.20 Example of Attribute data from a SPATSIM-HDSF database displayed in ArcGIS

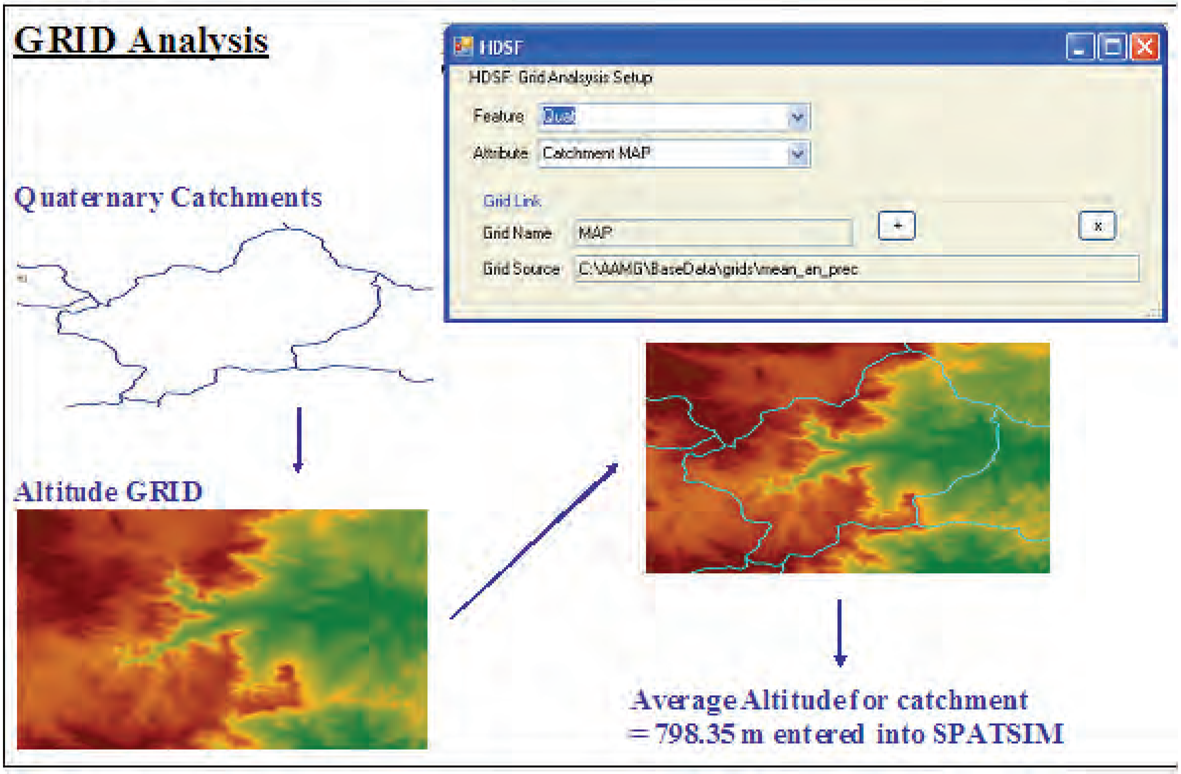


Figure 2.21 An example of the HDSF GRID analysis tool for ArcGIS

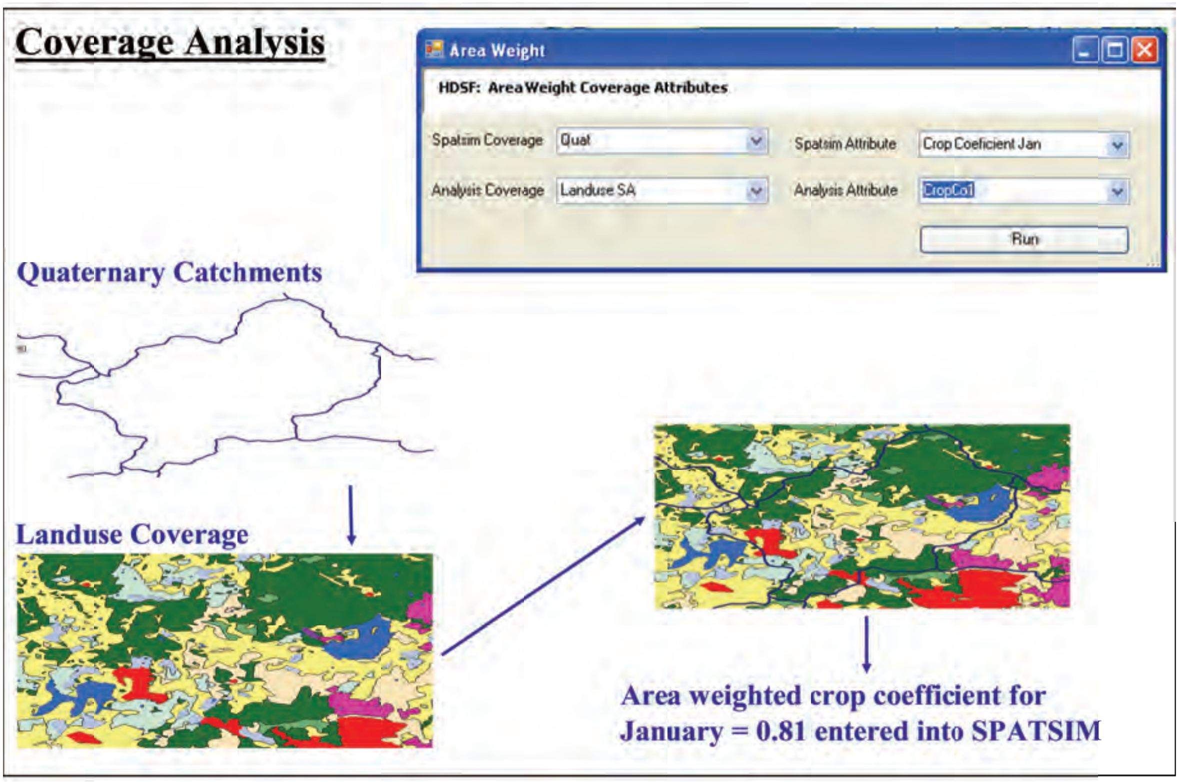


Figure 2.22 An example of the HDSF Coverage analysis tool for ArcGIS.

3. HOW TO PERFORM SELECTED TASKS

This chapter of the user manual contains a guide to the use of SPATSIM-HDSF, including installation instructions and instructions on how to perform various tasks.

3.1 Installation

The installation CD and user support may be obtained from the Institute for Water Research (IWR) for which contact details can be found in Section 7 .The “readme.txt” file found on the installation CD guides the user through five easy steps to install the SPATSIM-HDSF software. These steps are briefly listed below:

- Run setup.exe
- Run SETUP_Mo22rt.bat
- Run MDAC_TYP.exe
- Run dotnetfxV2.0.exe (Requires Windows XP Service Pack 2 to be installed)
- Run jre-6u7-windows-i586-p-s.exe.

Instructions for running the above steps are detailed in the following sections.

3.1.1 Step (i): Run Setup.exe

When “Setup.exe” is run from the installation CD, the first screen that will be displayed is the welcome screen, as shown in Figure 3.1, indicating that the SPATSIM-HDSF software is about to be installed. Select the *Next* button to proceed with the installation.

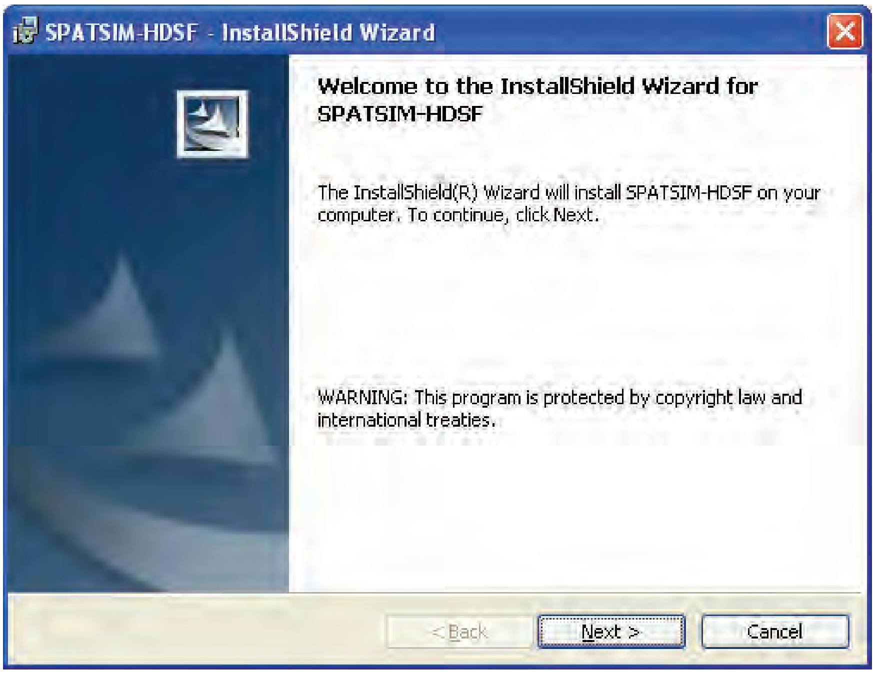


Figure 3.1 Install screen for SPATSIM-HDSF

The next screen of the installation wizard shown in Figure 3.2 displays the default destination folder to be used to install the SPATSIM-HDSF software. It is highly recommended to select the default "C:\HDSF\" folder as the example databases have been configured for this folder structure. A different installation location may be selected if required, however, changes will then need to be made to the SPATSIM-HDSF project INI file for the example databases to reflect this change in folder structure. Select *Next* to proceed with the installation.

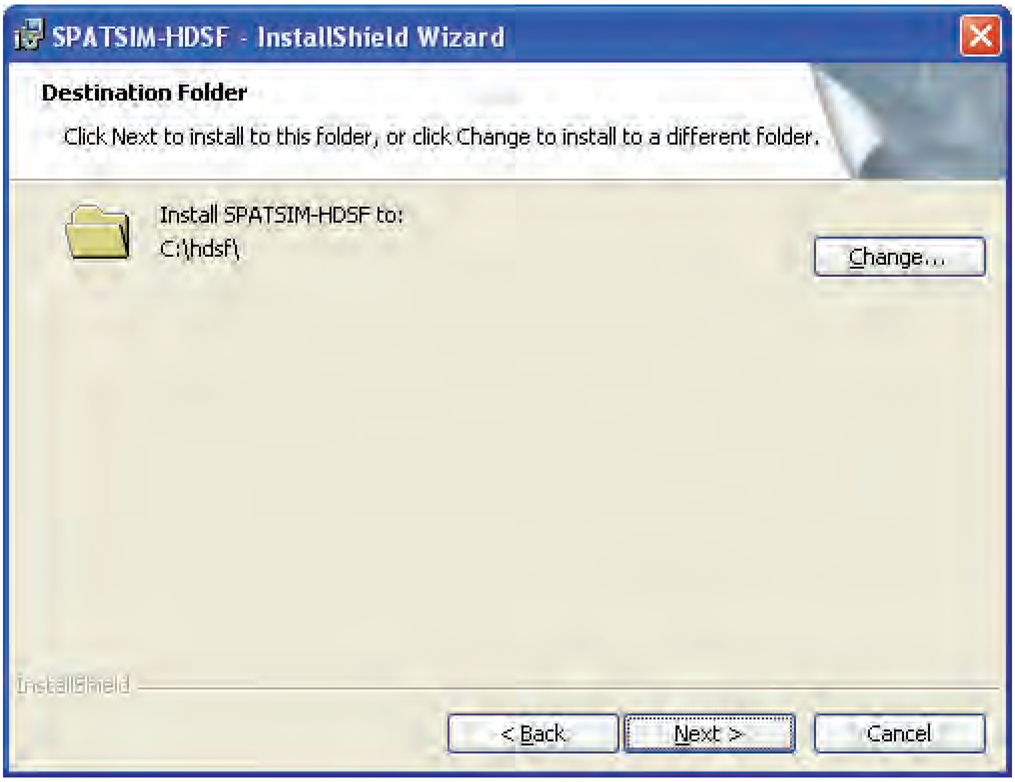


Figure 3.2 Destination folder selection

Once the installation destination folder has been selected then a summary of the selected options is displayed, as shown in Figure 3.3, and the *Install* button can be selected to proceed with the installation of SPATSIM-HDSF.

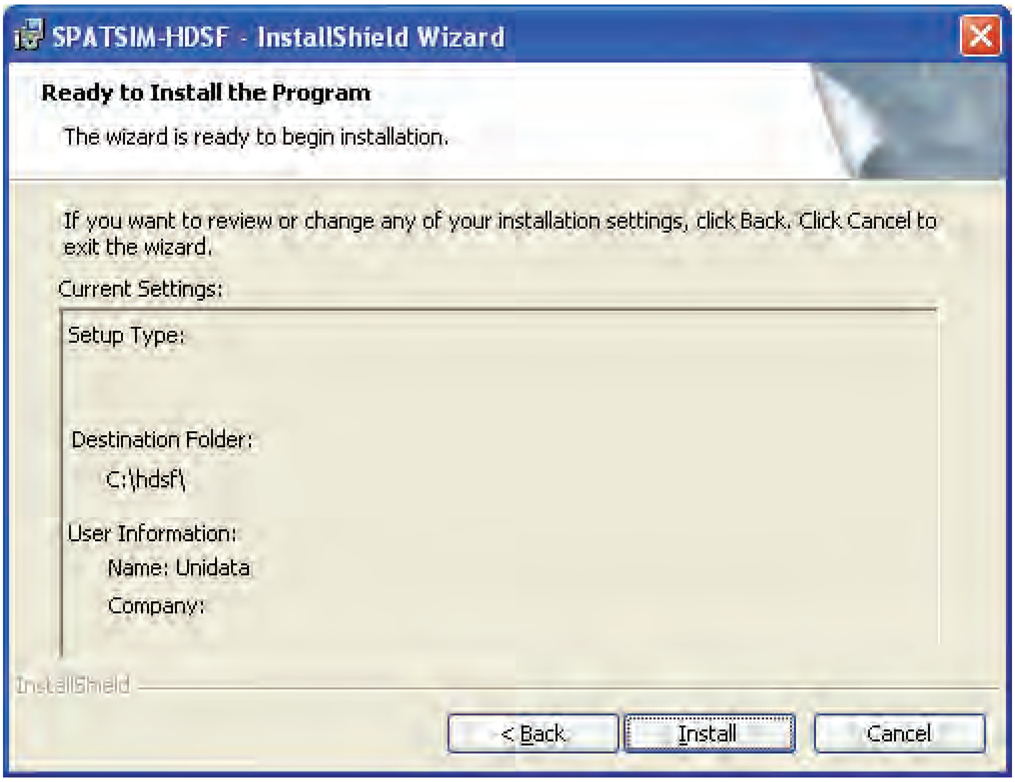


Figure 3.3 Summary of the selected install options

The installation progress screen shown in Figure 3.4 is displayed and the installation wizard will inform the user whether installation was successful or not as shown in Figure 3.5.

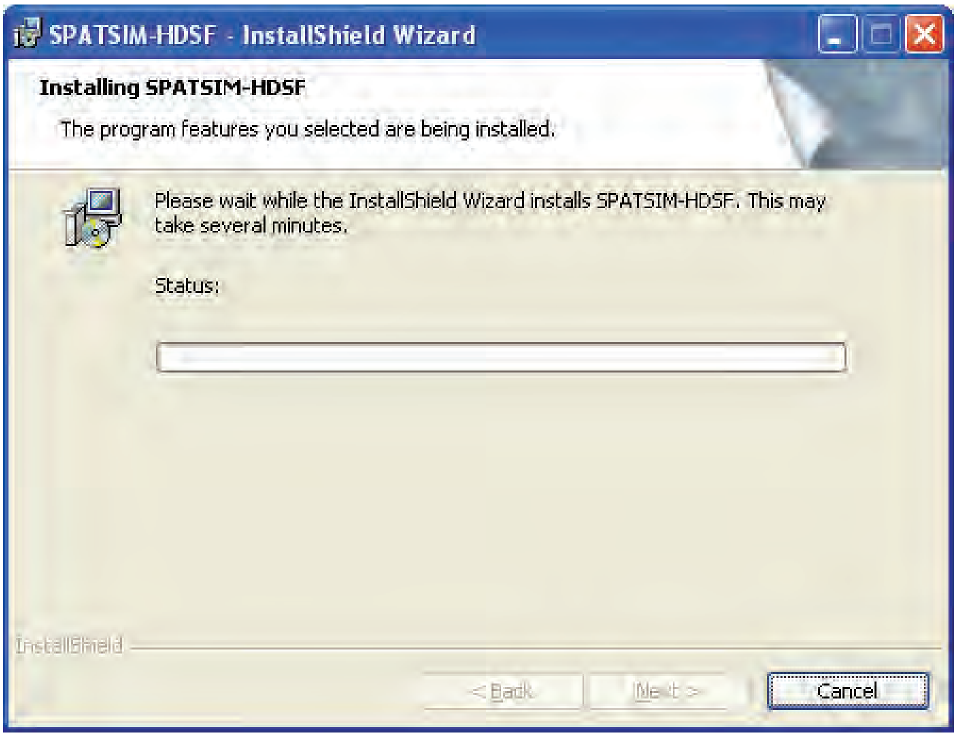


Figure 3.4 Install progress screen

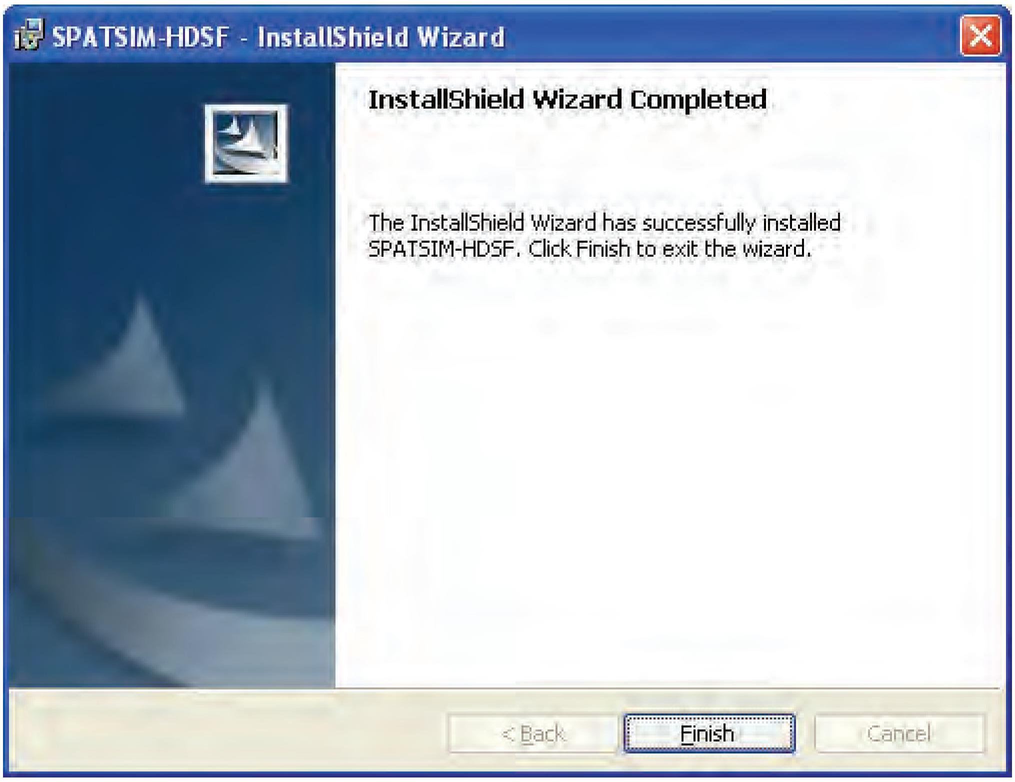


Figure 3.5 Successful installation screen

3.1.2 Step (ii): Run SETUP_Mo22rt.bat

Step (ii) is only required if Map Objects Version 2.2 is not installed on the user's computer. This can be checked by going to the computer's *Control Panel -> Add or Remove Programs* and looking to see if *ESRI MapObjects 2 Runtime* is listed in the *currently installed programs* list. If it is not listed then run the file "Setup_Mo22rt.bat", found on the installation CD, which should display a window as shown in Figure 3.6.

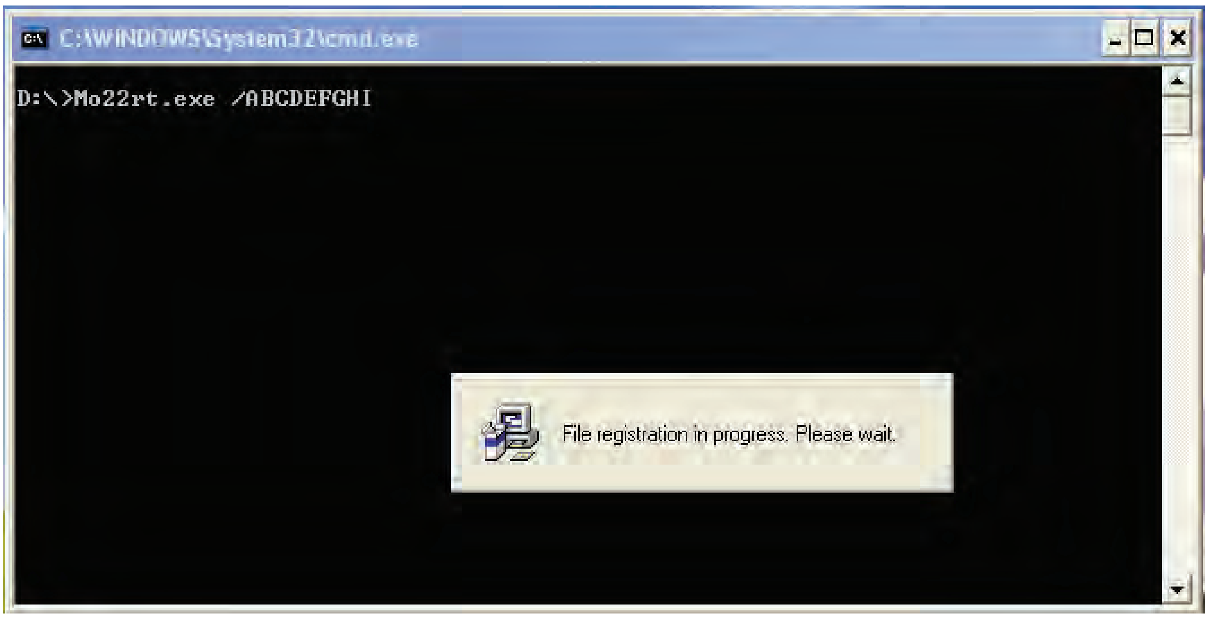


Figure 3.6 Running the Setup_Mo22rt.bat to install Map Objects Version 2.2

3.1.3 Step (iii): Run MDAC_TYP.exe

Step (iii) installs Microsoft Data Access Components which SPATSIM-HDSF utilises to read and write to Microsoft Access databases and is initiated by double clicking on the “MDAC_TYP.EXE” file name in Windows Explorer. If the Microsoft Data Access Components are already installed on the computer, then Figure 3.7 is presented to the user. Alternatively, the user is prompted to accept the End User Licence Agreement as shown in Figure 3.8 and then to complete the installation by clicking on the “Finish” button shown in Figure 3.9. If the installation prompts that there are newer files already on the computer, then choose the option to keep these files.

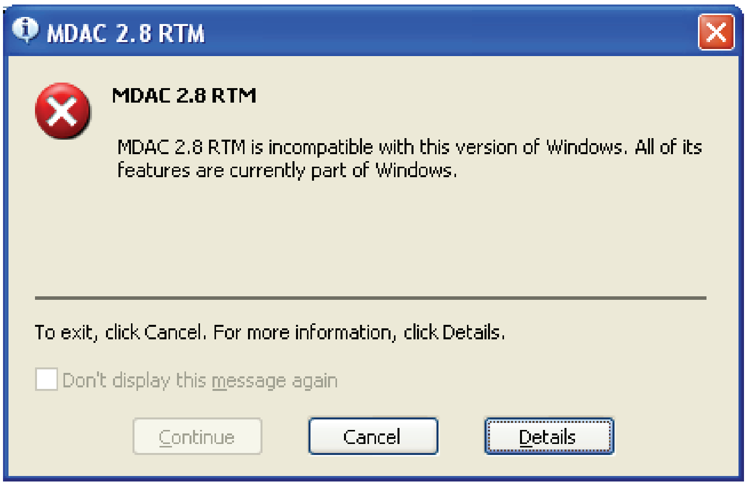


Figure 3.7 Screen indicating that the Microsoft Data Access Components are already installed on the computer

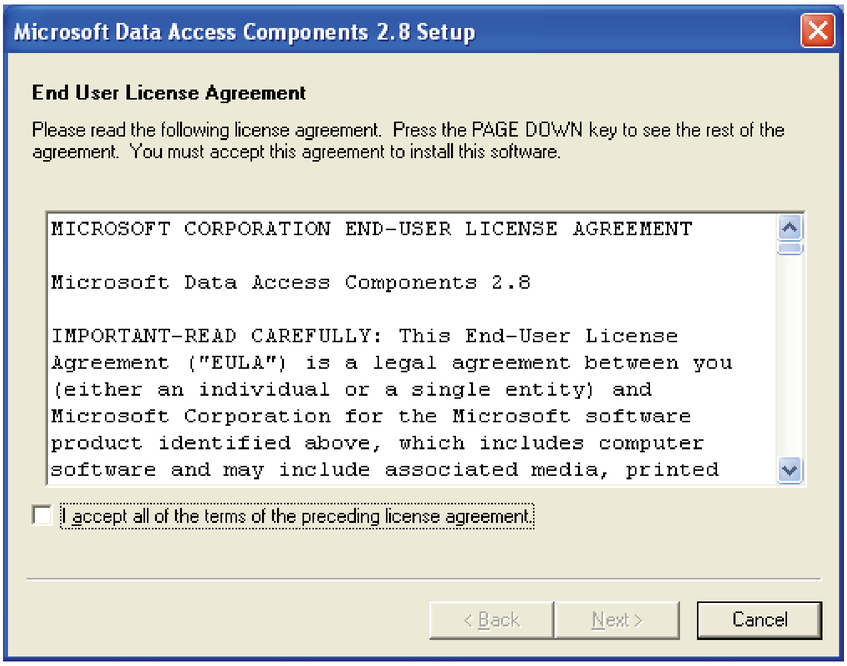


Figure 3.8 Microsoft End User Licence Agreement for Data Access Components

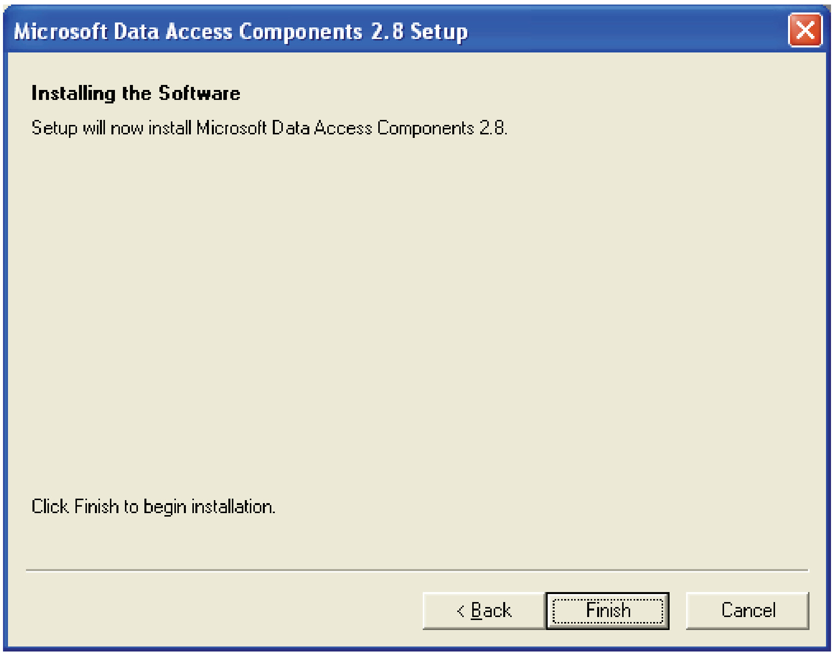


Figure 3.9 Installing the Microsoft Data Access Components

3.1.4 Step (iv): Run dotnetfxV2.0.exe

Step (iv) is only required if Microsoft .NET Framework 2.0 is not installed on the user's computer. Again this can be checked by going to the PC *Control Panel -> Add or Remove Programs* and looking to see if *Microsoft .NET Framework 2.0* is listed. If it is not listed then install it by running the file "dotnetfxV2.0.exe" also found on the installation CD. The installation requires the user to click on the *Next* button shown in Figure 3.10, then accepting the Microsoft End-User Licence Agreement, as shown in Figure 3.11 and completing the installation by clicking on the *Finish* button in Figure 3.12.

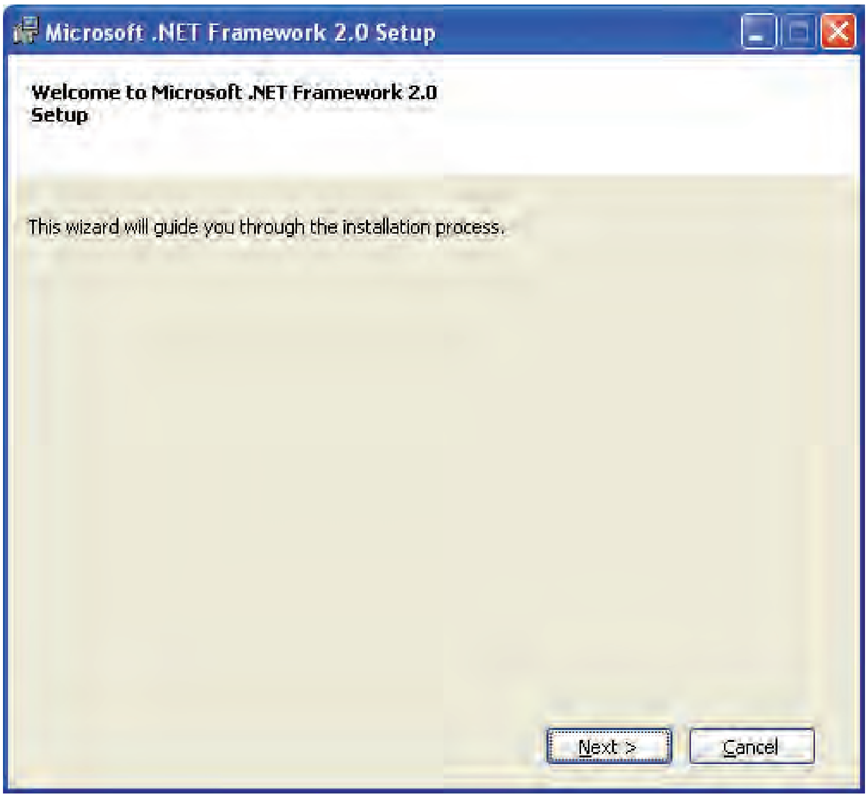


Figure 3.10 Initiation of installation of .NET framework

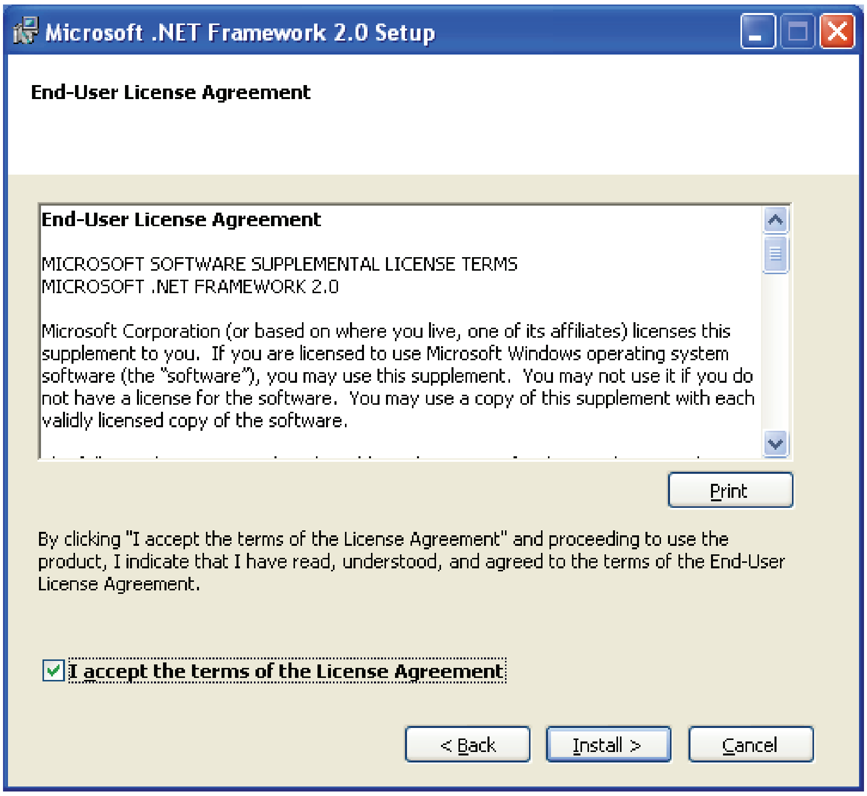


Figure 3.11 Microsoft End User Licence Agreement for .NET Framework

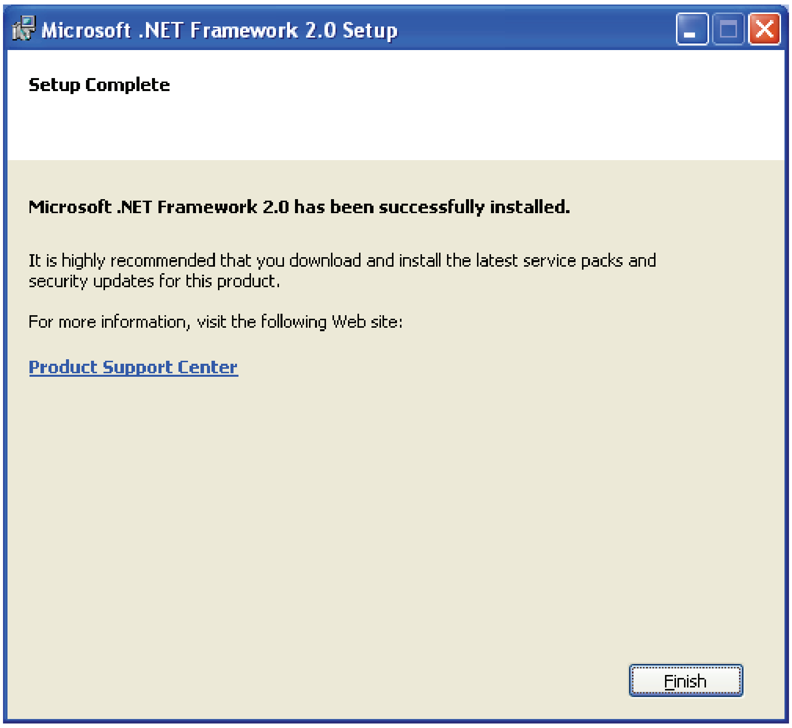


Figure 3.12 Successful completion of .NET framework installation

3.1.5 Step (v): Run jre-6u7-windows-i586-p-s.exe

Step (v) is only required if the Java Runtime Environment is not installed on the computer and is initiated by double clicking on the “jre-6u7-windows-i586-p-s.exe” file name found on the installation CD and then clicking the *Accept* button shown in Figure 3.13 and then *Finish* as shown in Figure 3.14.

Figure 3.13 Licence Agreement for Java installation

Figure 3.14 Successful completion of Java installation

3.2 Running SPATSIM-HDSF

If the above 5 steps have been successfully completed, then the SPATSIM-HDSF software is installed and can be run by clicking on the SPATSIM-HDSF icon placed on the Desktop.

3.3 Using the Main SPATSIM-HDSF User Interface

This section is written with a more hands on approach to demonstrate how to use the functionality of SPATSIM-HDSF. The layout of the main window in the SPATSIM-HDSF user interface is shown in Figure 3.15.

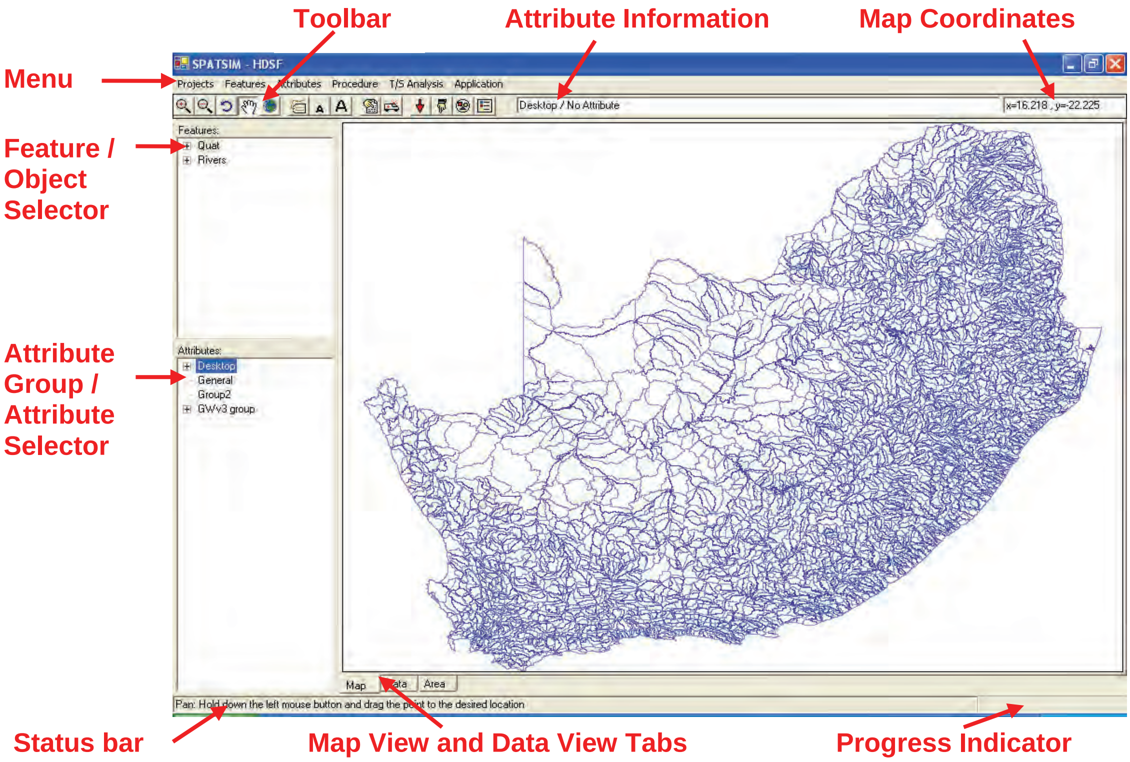


Figure 3.15 Main window in the SPATSIM-HDSF user interface

3.3.1 How to launch the Project Selection window

Once SPATSIM-HDSF has been started by double clicking on the SPATSIM-HDSF icon on the desktop, the *Project Selection* window will be displayed, as shown in Figure 3.16. Alternatively if a SPATSIM-HDSF project is already open, select *Projects -> Open* from the menu which will also open the *Project Selection* window.

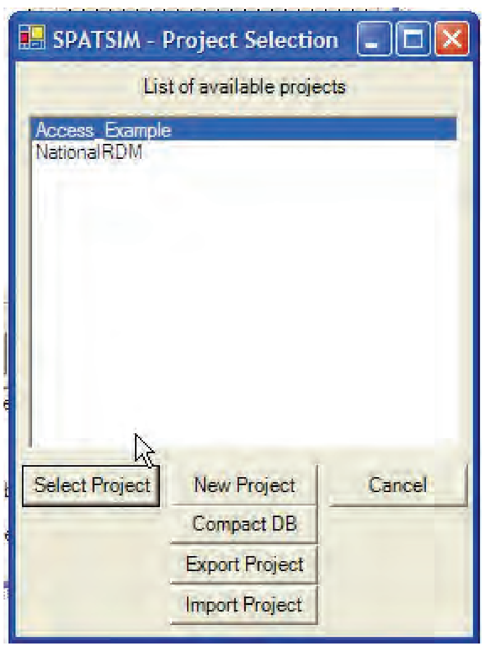


Figure 3.16 Example of the *Project Selection* window

The *Project Selection* window of SPATSIM-HDSF includes options to create new projects and open or compact existing projects, which is useful for management of modelling projects and scenarios.

Each project has a Microsoft Access database file associated with it, contained in the *dbdata* folder within a SPATSIM-HDSF project folder as explained in Section 5.1. Microsoft Access databases have a tendency to retain disk space of deleted data. Compacting an existing project, reduces this extra disk space thus reducing the disk space that a SPATSIM-HDSF project uses.

3.3.2 How to make a new SPATSIM-HDSF project

Creating a new project is a simple process where all the required data folders and an empty SPATSIM-HDSF database will be created automatically. The following steps should be followed to create a new SPATSIM-HDSF project:

- In the *Project Selection* window, select the *New Project* button as shown in Figure 3.17.
- You will be prompted for a name for your new SPATSIM-HDSF project. Enter a meaningful project name and select the *OK* button as shown in Figure 3.18.
- The next prompt as shown in Figure 3.19 is for the folder name\path where this project will be stored. It will default to the same name used for the project and will be created in the *HDSF* folder.
- Next the *cover* and *data* paths are setup and these are defaulted to subfolders called *cover* and *data* within your project folder as shown in Figure 3.20 and as shown in Figure 3.21.
- The last message as shown in Figure 3.22 is a confirmation to create the project, select *OK* to complete the creation of a new SPATSIM-HDSF project.

- Please note that you should not use any spaces in the name of the project or in any of the folder names.

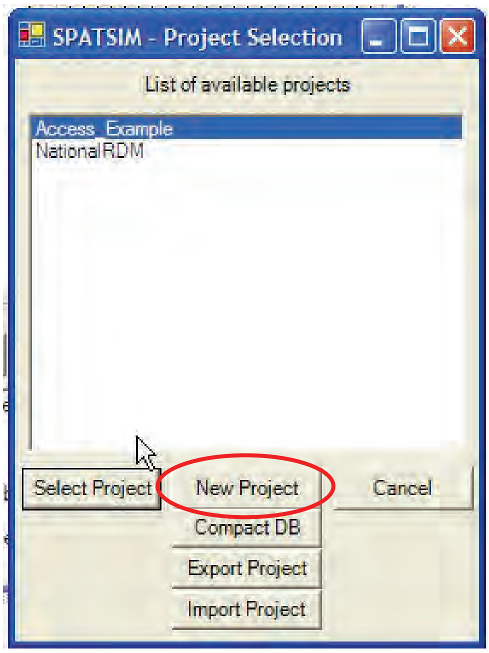


Figure 3.17 Starting a new project

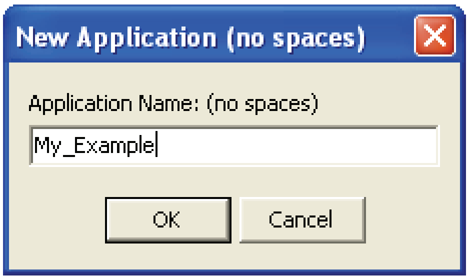


Figure 3.18 Project name (This creates a project INI file with this name)

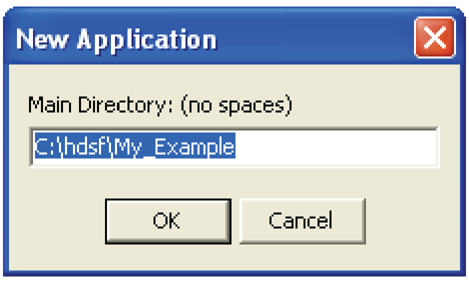


Figure 3.19 Project path

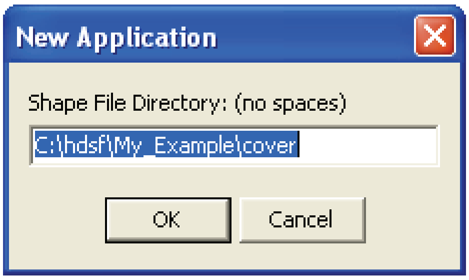


Figure 3.20 Cover path (‘cover_dir’ in the project INI file)

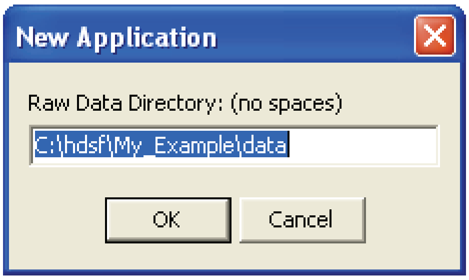


Figure 3.21 Data path (‘dat_dir’ in the project INI file)

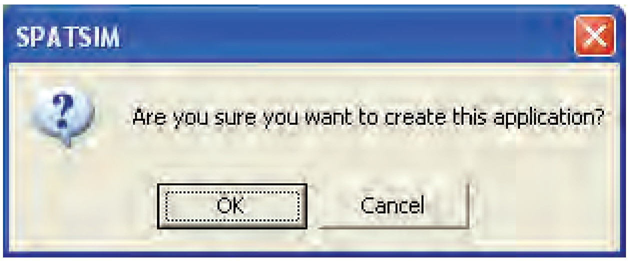


Figure 3.22 Project confirmation

3.3.3 How to open an existing project

Launch the *Project Selection* window, then select the project from the list of available projects, then press the *Select Project* button to open the project as shown in Figure 3.23.

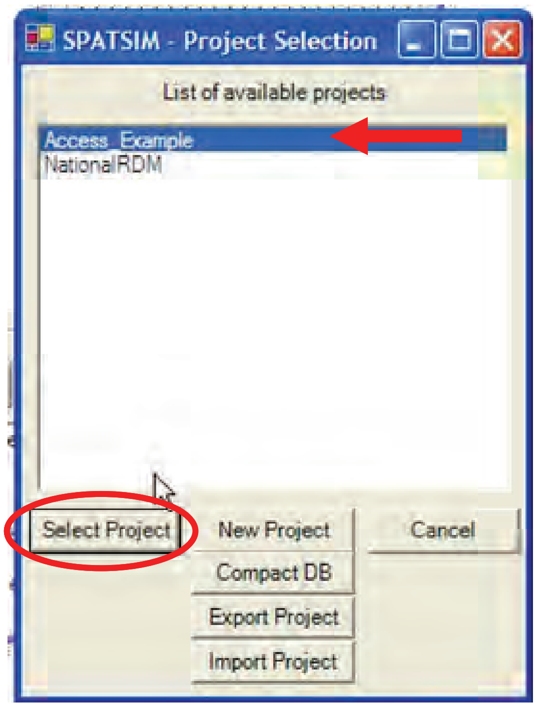


Figure 3.23 Opening an existing SPATSIM-HDSF project

A short cut is to double click on the project in the list.

3.3.4 How to compact a project database

The database technology being used for the SPATSIM-HDSF application can result in the database associated to a project becoming large due to operations carried out within SPATSIM-HDSF. To counter this increase in size, the database technology offers the option to compact a database to reduce its size. In the *Project Selection* window, there is an option called *Compact DB* button as show in Figure 3.16. Clicking on the *Compact DB* button will compact the database of the associated project.

3.3.5 How to export an existing project

Exporting an existing project is a simple process as all the required data of the SPATSIM-HDSF project will be copied automatically to an export folder. This folder can be distributed to be imported into another SPATSIM-HDSF installation. The following steps should be followed to export a SPATSIM-HDSF project:

- In the *Project Selection* window, select the project to be exported and click the *Export Project* button as shown in Figure 3.16.
- The *Export a Project* window will be displayed as shown in Figure 3.24, with the default location for the export folder already chosen. If this needs to be changed, do so by selecting the *Browse* button from the *Export a Project* window.

- Click the *Export* button. A ClientID is requested as shown in Figure 3.25. The Client ID is needed to keep track of changes made by a consultant or other user to an exported project, which aids in the exporting, importing and the merging process of a project.
- Finally a window displaying the location of the exported project folder is displayed as shown in Figure 3.26. This export project folder will be used to import the project to another SPATSIM-HDSF installation. In Figure 3.26 the export project folder is *C:\HDSF\export\Lions*.

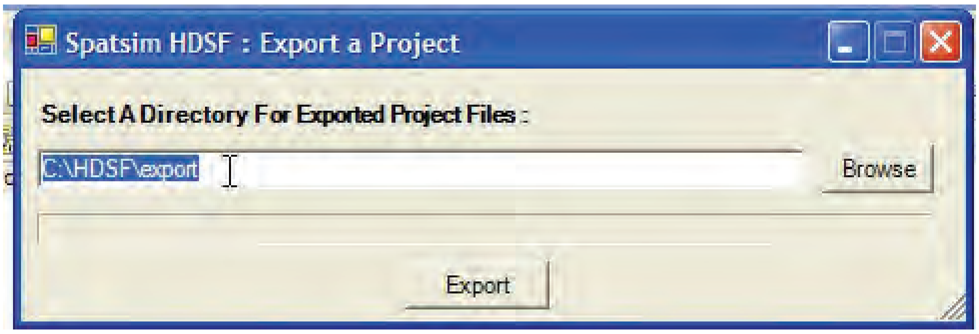


Figure 3.24 Export a Project window

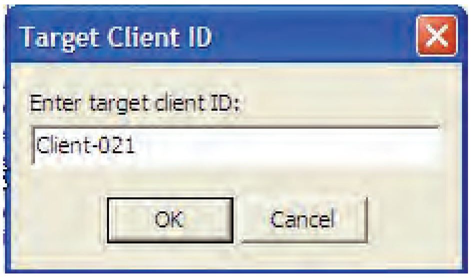


Figure 3.25 Window requesting Client ID to track changes made to a project

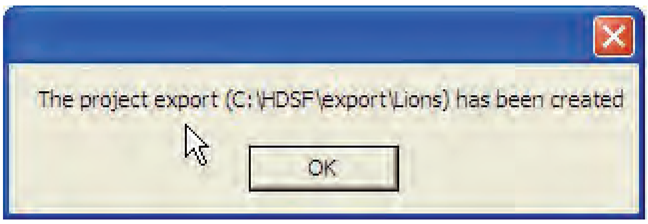


Figure 3.26 Window displayed after successful completion of Export process

3.3.6 How to import a project

To carry out this process an export folder created in the previous step is needed with its associated project INI file. This will be used to import the project into the SPATSIM-HDSF application. The following steps should be followed to import a SPATSIM-HDSF project:

- In the *Project Selection* window, select the *Import Project* button as show in Figure 3.16.
- The *Import a Project* window is displayed as show in Figure 3.27. A valid exported project INI file needs to be selected and can be found within the exported project directory being imported. Browse for this file by clicking on the *Browse* button as show in Figure 3.27.
- Click on the *Import* button to import the project. If the project being imported conflicts with the name of an existing project within the SPATSIM-HDSF application, a new name will be requested.
- A window displaying the name of the successfully imported project appears when the import process is completed as shown in Figure 3.28.

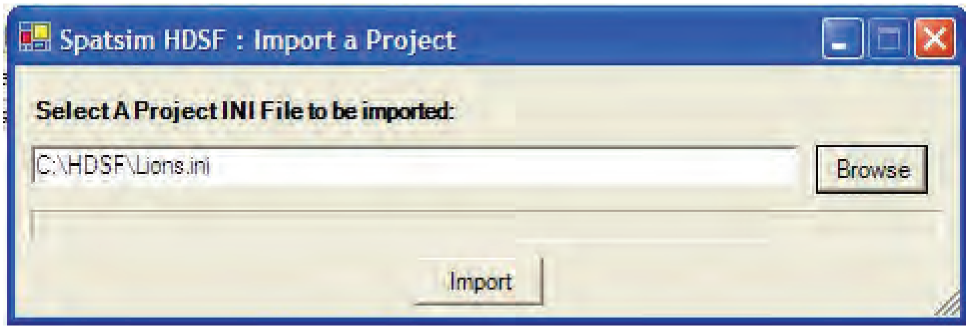


Figure 3.27 Import a Project window

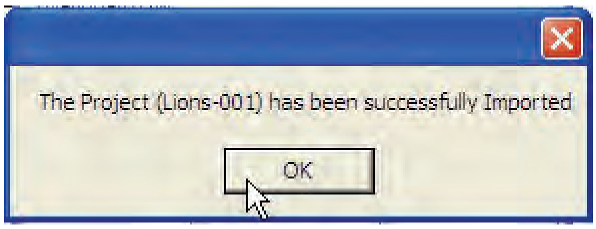


Figure 3.28 Window displayed after successful completion of import process

3.3.7 How to add a new Feature

As explained in Section 1.3 three types of Feature, spatial, non-spatial and image, may be added to a SPATSIM-HDSF project. Spatial Features are represented by an ESRI shape file containing polygons, lines or points. Non-spatial Features are represented by a table within the database. Image Features are represented by a geo-referenced image. Each shape file or non-spatial Feature table should have at least two fields that can be easily recognised for reference: an ID field (*ID Field*) containing a unique integer number for each spatial element and a description field (*Desc.Field*) containing a unique text string that identifies each spatial element.

Within SPATSIM-HDSF, the integer values in the *ID Field* are used as a cross-reference to data stored in other database tables. The *Desc. Field* information can be displayed for identification purposes, but it is also used by the data import facilities (see various help options including 'Exchange Data' and 'Importing Data'). The *Desc. Field* can be changed after the Feature has been added to the database, however, the *ID Field* must remain fixed. Information in the *Desc. Field* can also be edited, while the *ID Field* numbers must remain fixed.

Use the *Features -> ID DESC Fields -> Edit Fields* or *Edit Data* main menu options to change the shape file field to use as the *Desc. Field* or to edit the *Desc. Field* data values.

How to add a new Spatial Feature

For spatial Features it is recommended that for you first place a copy of the shape files into the *cover* folder in your project. However, shape files may be shared between SPATSIM-HDSF projects if required by specifying a common *cover* folder.

From the SPATSIM-HDSF menu shown in Figure 3.29 select *Features -> Add -> New -> Spatial*.

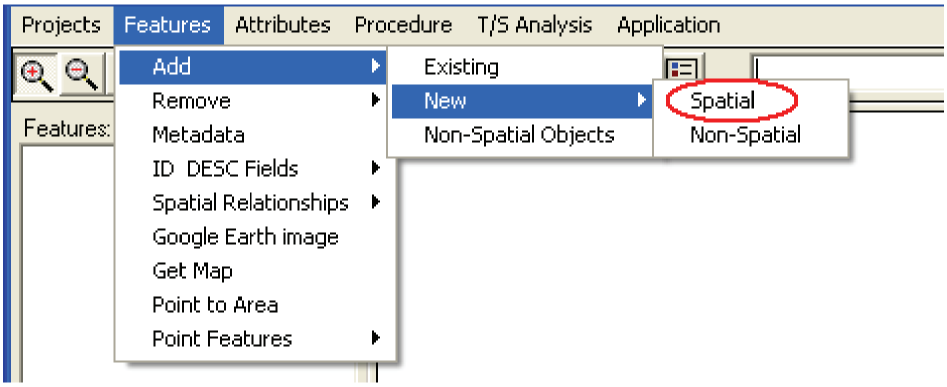


Figure 3.29 Selecting the option in the menu to add a new spatial Feature

An *Open* file dialog window opens as shown in Figure 3.30, enabling you to search for shape files from any folder, but the default path is the *cover* folder in your project. Select the shape file you are looking for and then click the *Open* button.

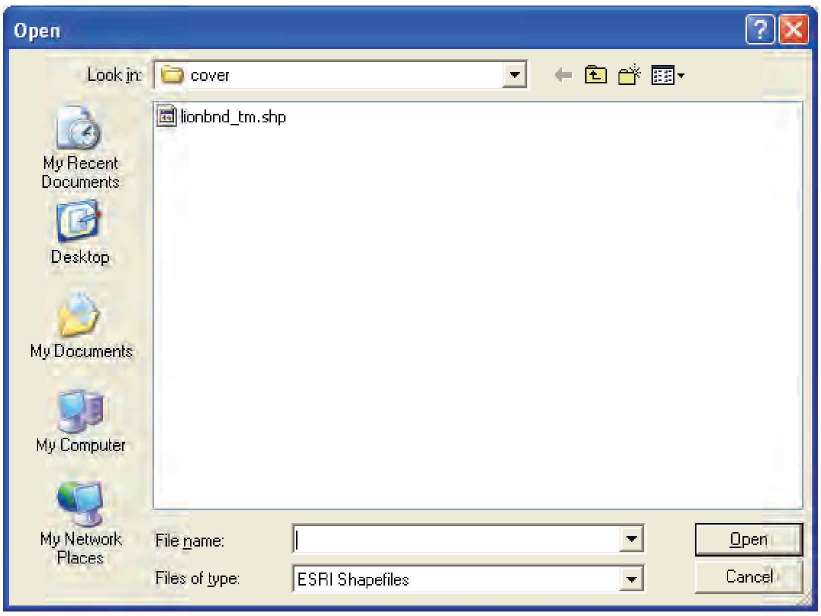


Figure 3.30 Example of the *Open* file dialog window

The *Feature Name* window will be displayed as shown in Figure 3.31 and you will be prompted to enter a unique name for the new Feature.

Figure 3.31 Example of the *Feature* name

The ID field (*ID Field)* and description filed (*Desc. Field)* are fields in a shape file that uniquely identify individual spatial elements.

The ID field must contain integer numbers and remains fixed once the new Feature has been loaded. The contents of the field must not be changed (by an external program, for example) as this is used as the cross-reference to the Attribute data within the database.

The description field can be text or numbers, can be changed at any time and the contents of the field can be edited for any spatial element. However, note that the information in this field is used to control many of the data exchange and data import routines.

The *Feature Selection* window, as shown in Figure 3.32, will then open displaying all the fields in the shape file from which the user will need to select an ID field and a description to be used by SPATSIM-HDSF for referencing and identifying spatial elements. It is important that suitable fields exist in the shape file before attempting to add a Feature (use ARCVIEW or similar software to add new shape file fields as required). As shown in Figure 3.32, the selection process is as follows:

- select the field to be used as ID field,
- click the *Set ID Field* button to set the selected field,
- select the field to be used as description field,
- click the *Set Desc. Field* button to set the selected field, and finally
- select *OK* to finish.

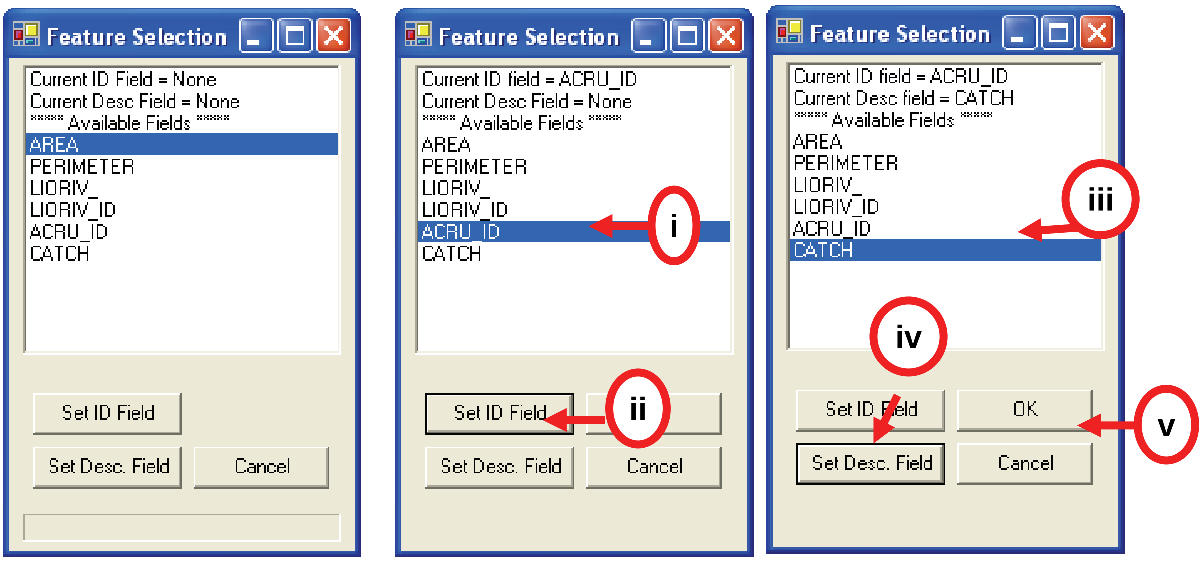


Figure 3.32 Selecting the new Feature's *ID Field* and *Desc. Field*

Once a new spatial Feature has been added the following will be displayed as shown in Figure 3.33:

- The Feature name is automatically added to the Feature and Object Selector.
- As this is a new Feature no Attribute Groups or Attributes exist yet except for the default Attribute Group called *General* which is displayed in the Attribute Group and Attribute Selector. The procedure for adding Attribute Groups and Attributes is explained further in Section 3.3.22 and Section 3.3.25.
- The shape file is displayed in the Map View.

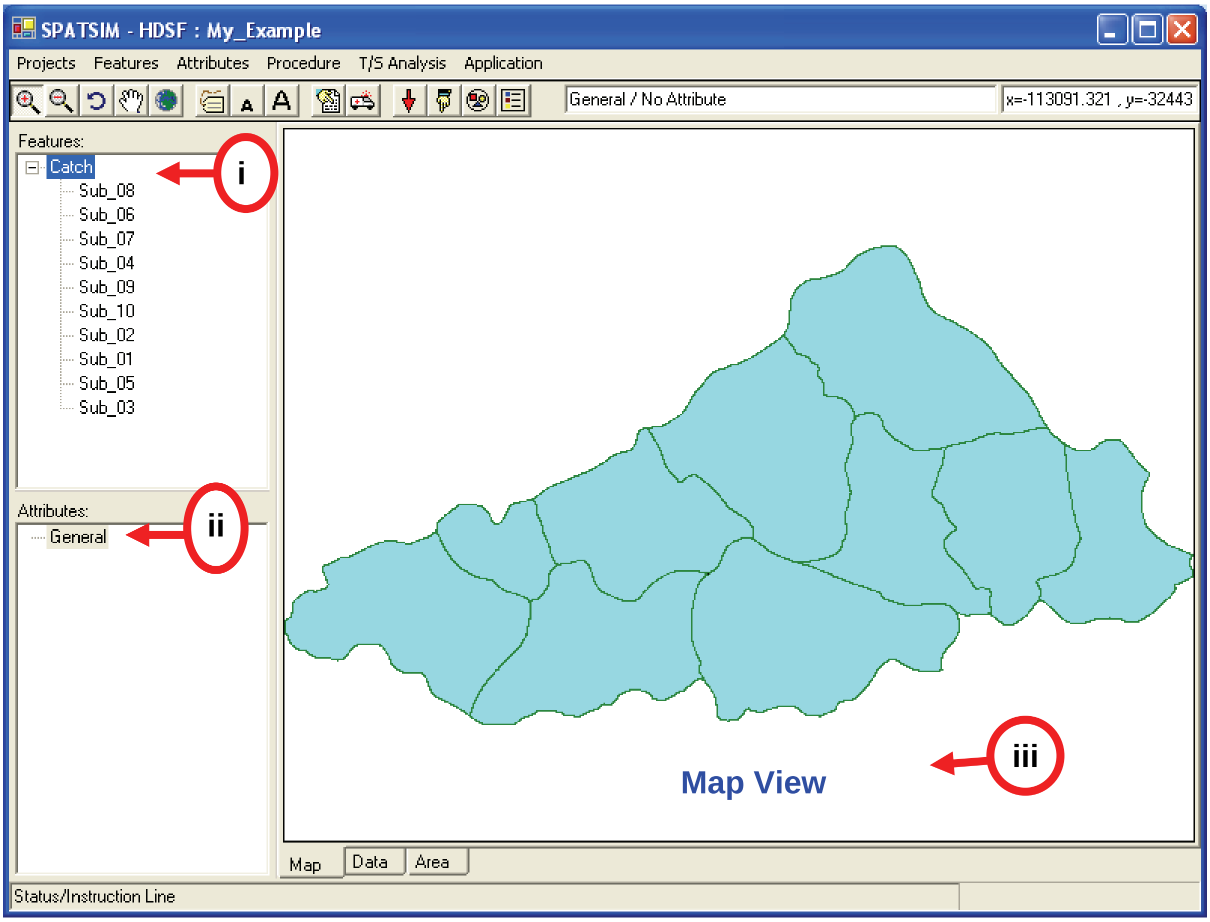


Figure 3.33 Example of a spatial Feature displayed in the *Map* tabbed page

Once a Feature has been added to the SPATSIM-HSDF database it can be displayed during any run of SPATSIM-HDSF using the *Features ->Add -> Existing* menu option. If a SPATSIM-HDSF project is closed, the currently displayed Features are remembered in the project INI file and will be displayed again the next time the SPATSIM-HDSF project is loaded.

Features can also be removed from the spatial view, or from the database. If the latter option is selected, then all Attributes and Attribute value data associated with that Feature are removed from the database as well. Use the *Features->Remove->From View* or *From Database* menu options.

Changing between Features (to make a different Feature the current selected Feature) is done by simply clicking on the required Feature name in the Feature and Object Selector. The new Feature is drawn on top and its list of associated Attribute Groups and Attributes is displayed in the Attribute Group and Attribute Selector below.

How to add a new Non-Spatial Feature

From the menu select *Features -> Add -> New -> Non-Spatial*. See Figure 3.34.

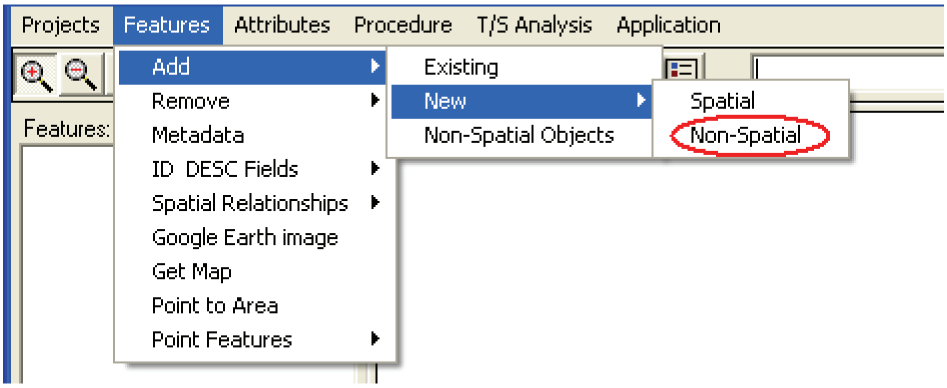


Figure 3.34 Selecting option in the menu to add a new non-spatial Feature

Enter a unique *Feature Name* and if required any useful metadata into the appropriate fields then select the *Add* button. An example of the *Add New Non-Spatial* Feature window is shown in Figure 3.35.

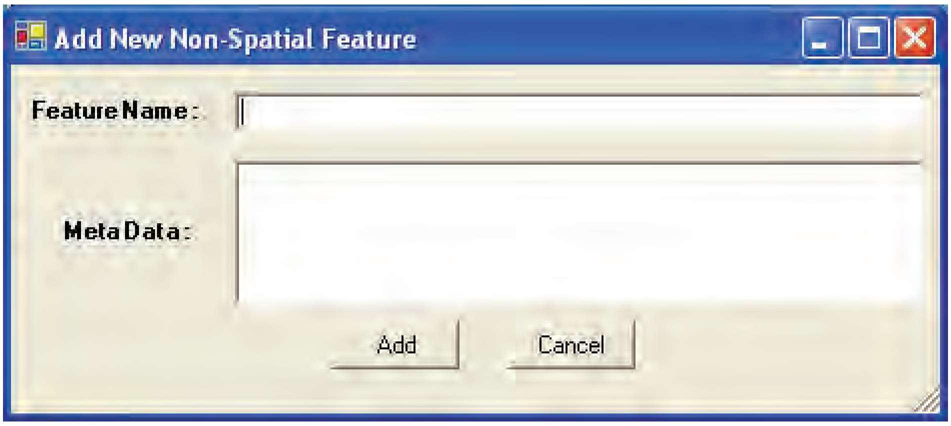


Figure 3.35 *Add New Non-Spatial Feature* window

This new non-spatial Feature will be added to the Feature and Object Selector but as it is non-spatial there will be no associated map shown in the Map View.

The next step would be to add objects to the non-spatial Feature as explained in Section 3.3.8. Once objects have added to the non-spatial Feature, then Attribute Groups with their associated Attributes can be assigned to the non-spatial Feature as explained in Section 3.3.22 and Section 3.3.25.

How to add an Image Feature

For image Features it is recommended that you first copy the image files into the *cover* folder in your project. For Google Earth images a Worldfile (.jpw) needs to be created first before it can be added as an image Feature. Creating a Worldfile for a Google Earth image is described in Section 3.3.17.

As shown in Figure 3.29 in the menu select *Features -> Add -> New -> Spatial*. A *Open* file dialog window as shown in Figure 3.36 will open. Select *Image Files (with* *world file)* from the *Files of type* dropdown list, enabling you to search for image files from any folder, but the default path is the *cover* folder in your project. Select the image file you are looking for and then click the *Open* button. An image layer is created with the image selected and displayed in the *Map* tabbed page as shown in Figure 3.37.

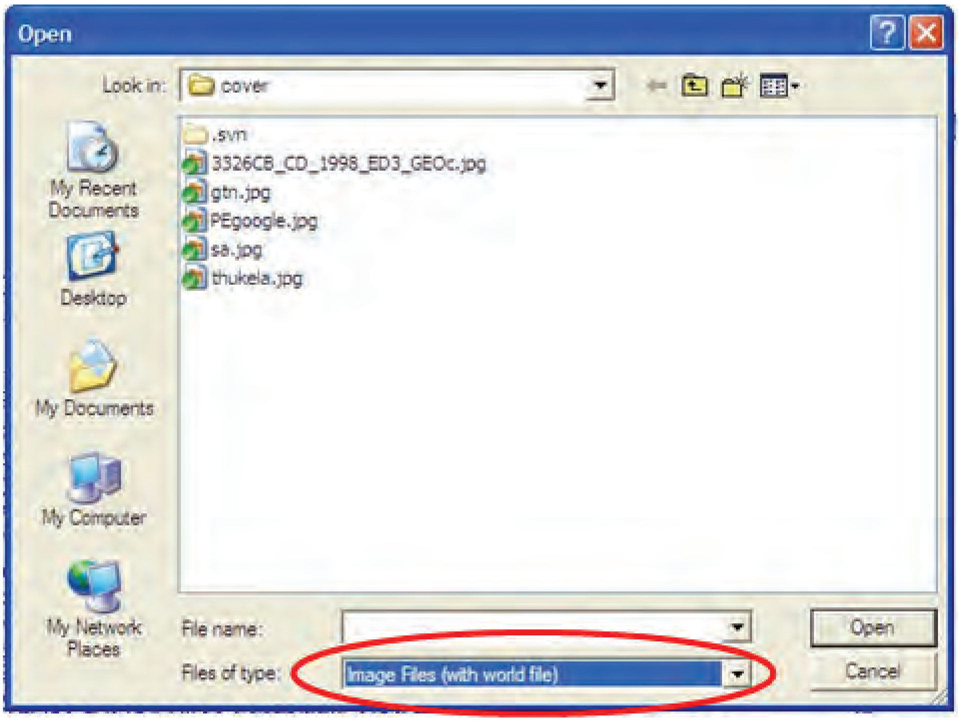


Figure 3.36 Open dialog box with Image Files (with world file) selected under Files of type

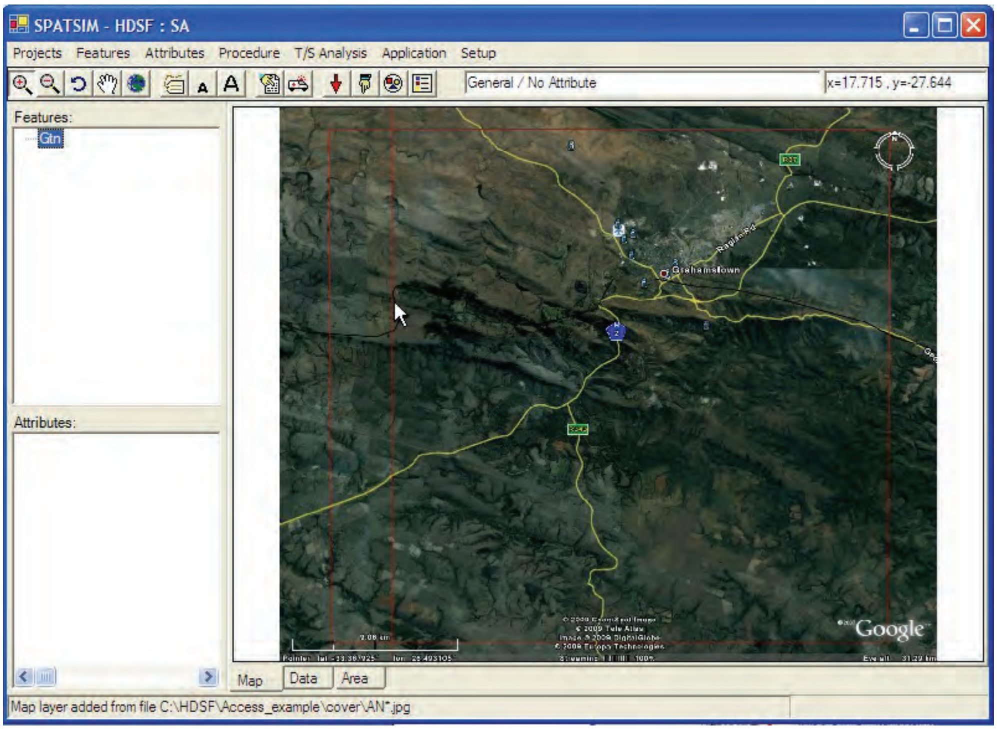


Figure 3.37 Image Feature display

3.3.8 How to add Objects to a Non-Spatial Feature

The term Feature in SPATSIM-HDSF refers to the GIS concept of a feature as being a collection of similar spatial elements sharing the same Attributes. For example, a catchments feature is a collection of polygons representing the boundaries of a set of catchments. A group of non-spatial elements will also be referred to as a Feature. Example of a non-spatial Feature is a set of industrial water users, their exact spatial location is not important but their demand for water is important. These spatial and non-spatial elements are known as objects. This section describes the process of adding objects to a non-spatial Feature.

The objects to be added to a non-spatial Feature can be imported from a comma separated file (CSV). The CSV file should contain the objects to be imported in one of the columns within the CSV file. The column should contain unique Object names or descriptions. This column is known as the description field.

From the menu select *Features -> Add -> Non-Spatial Objects* as shown in Figure 3.38.

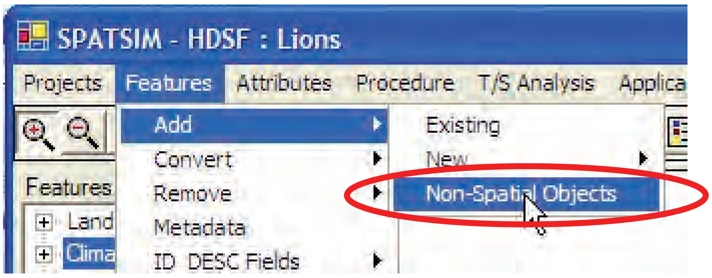


Figure 3.38 Adding Selecting the menu option to add *Non-Spatial Objects* to an existing non-spatial Feature

An *Open* file dialog window will open enabling you to search for CSV files from any folder, but the default path is the co*ver* folder in your project. This *Open* file dialog window is shown in Figure 3.39. Select the CSV file you are looking for and then click the *Open* button.

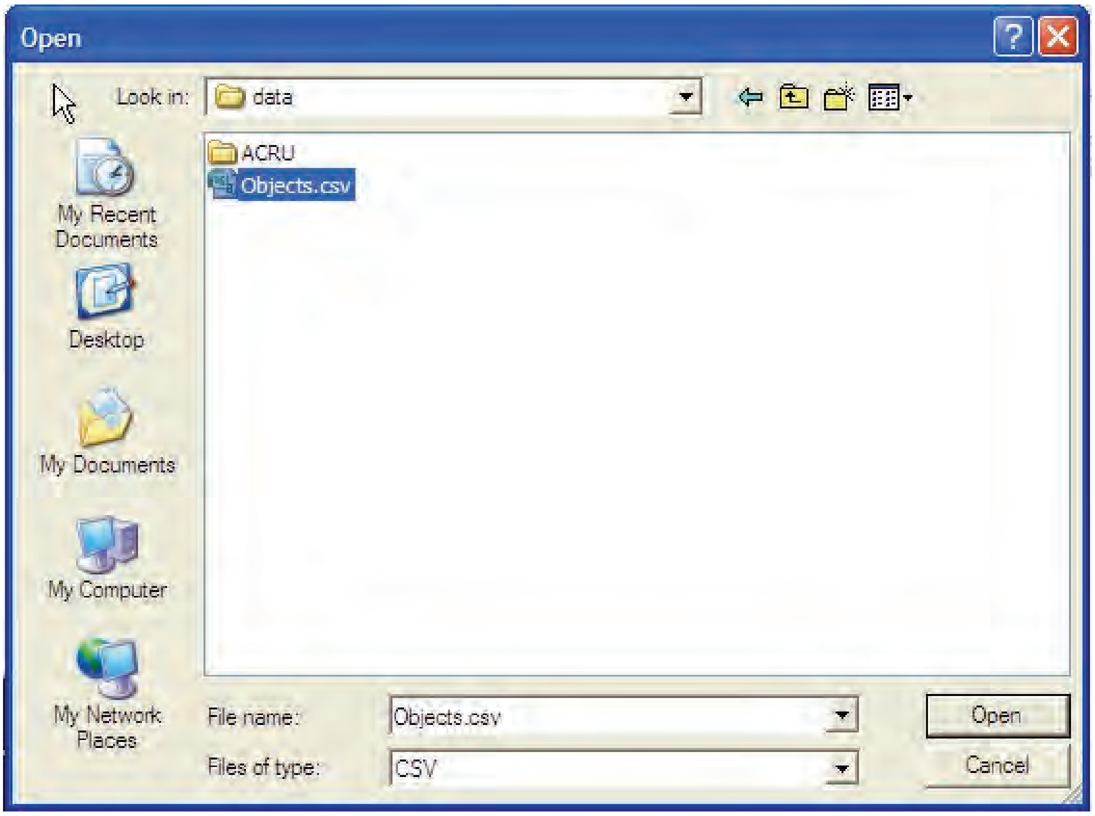


Figure 3.39 Open Dialog Box

The *Importing Non-Spatial Objects* window is displayed as shown in Figure 3.40. The user should then use the *Description Field (Unique)* field to select the column that contains the Object descriptions within the CSV file. The user should then use the *Non-Spatial Table* field to specify the name of the non-spatial Feature into which the objects are to be imported. Finally, complete the process by clicking on the *Read Data* button. The objects will be displayed in the *Data* list box. Once you have validated the objects in the list are the objects that will be imported to the non-spatial Feature, click *Import Data* button. A message box will be displayed indicating whether the addition of the objects was successful.

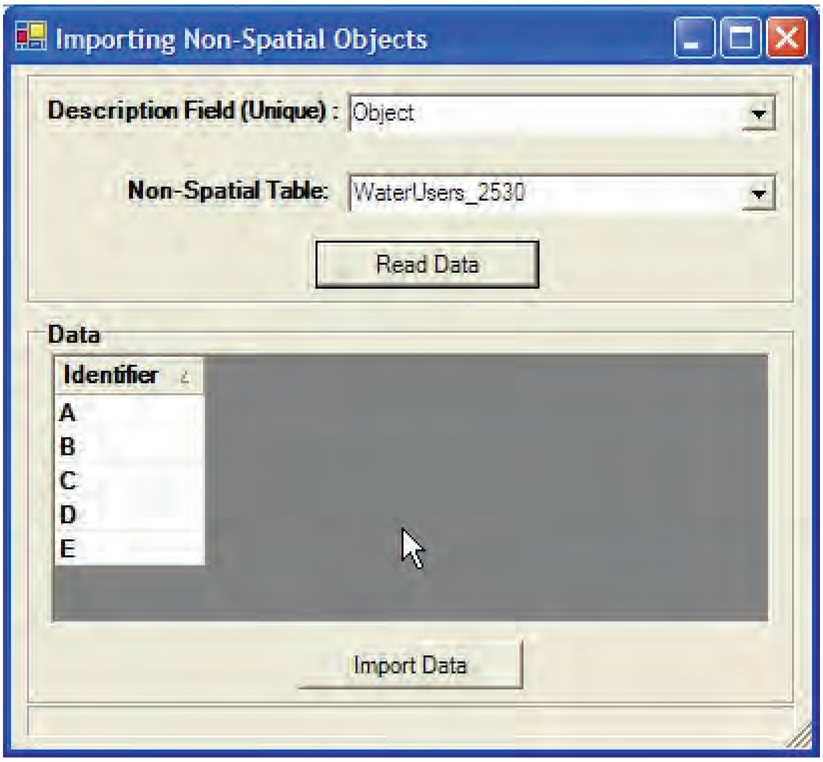


Figure 3.40 Importing Non-Spatial Objects window

3.3.9 How to convert a Non-Spatial Feature to a Spatial Feature

From the menu select *Features -> Convert -> Non-Spatial to Spatial*. An *Open* file dialog window as shown in Figure 3.41 will open enabling you to search for shape files from any folder, but the default path is the *cover* folder in your project. Select the required shape file and then click the *Open* button.

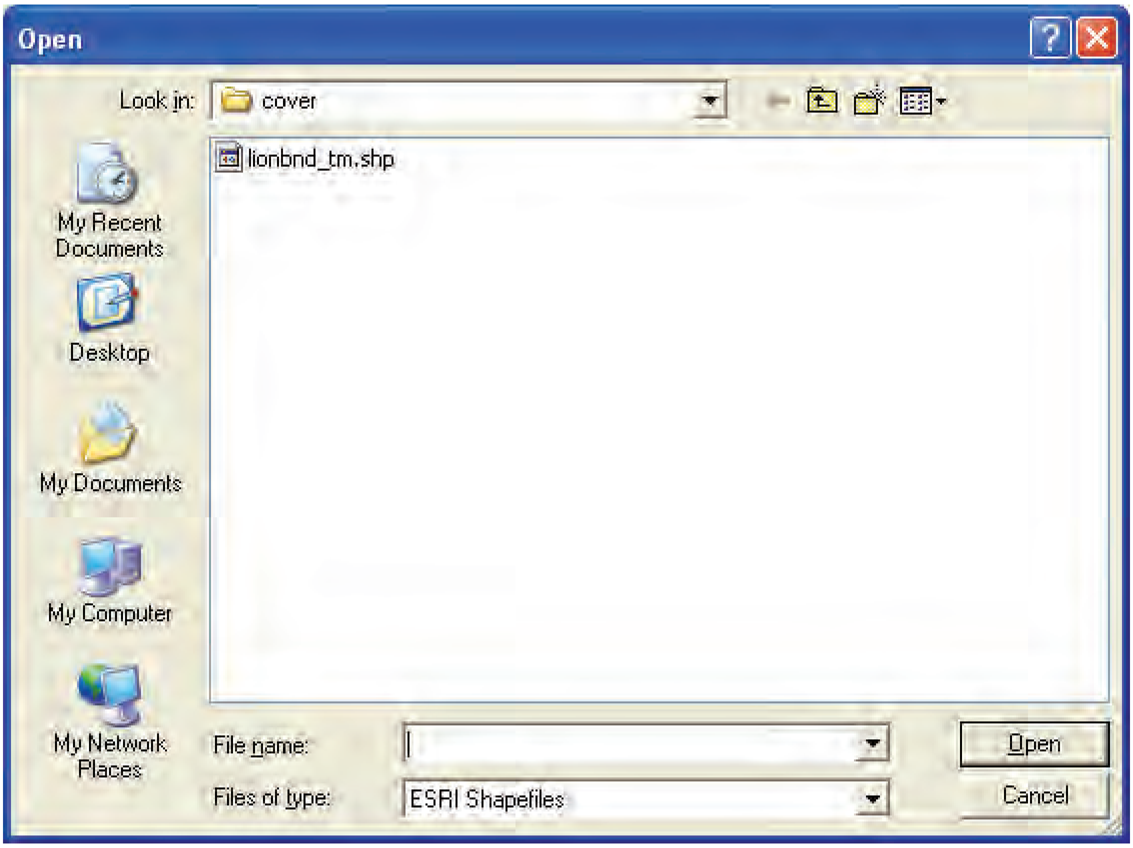


Figure 3.41 Example of the *Open* file dialog window

The *Feature Selection* window will be displayed, as shown in Figure 3.42, displaying all the fields in the shape. The user will need to select the an *ID* field and a *Desc. Field* to be used by SPATSIM-HDSF for referencing and identifying spatial elements. It is important that suitable fields exist in the shape file before attempting to add a Feature (use ARCVIEW or similar software to add new shape file fields as required).

As shown in Figure 3.42 , the selection process is as follows:

- select the field to be used as ID field.,
- click the *Set ID Field* button to set the selected field.,
- select the field to be used as description field.,
- click the *Set Desc. Field* button to set the selected field., and finally
- select *OK* to finish.

Once the *OK* button is clicked the non-spatial Feature is converted to a spatial Feature and the Feature and Object Selector in the navigation panel is updated, displaying the converted spatial Feature with its objects.

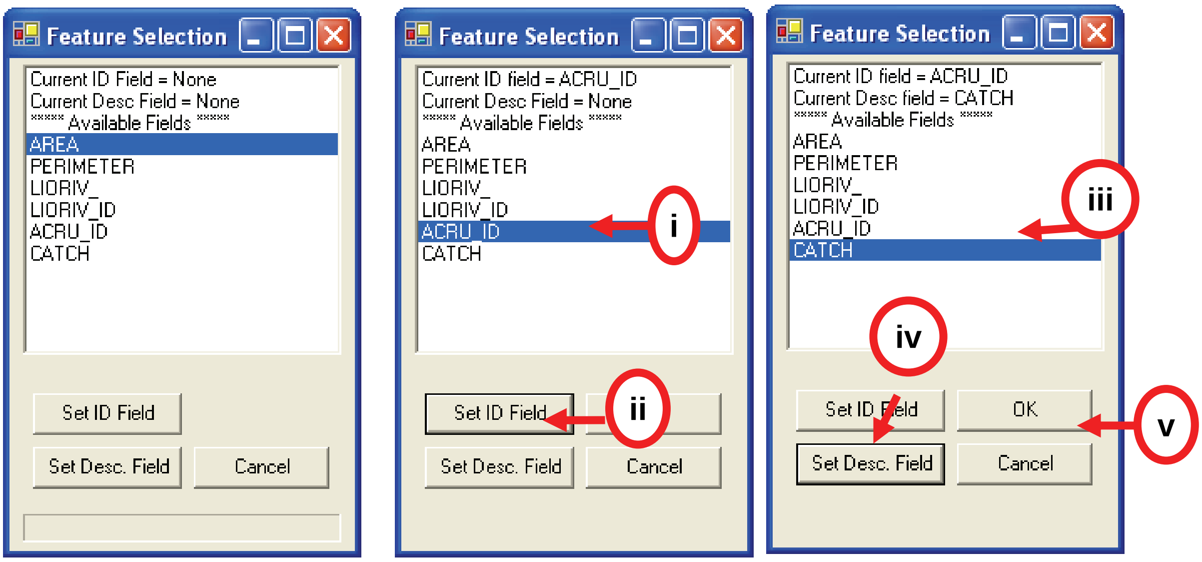


Figure 3.42 Selecting the spatial Feature's *ID Field* and *Desc. Field*

3.3.10 How to display/hide an existing Feature

To display an existing Feature select *Features -> Add -> Existing* from the menu as shown in Figure 3.43.

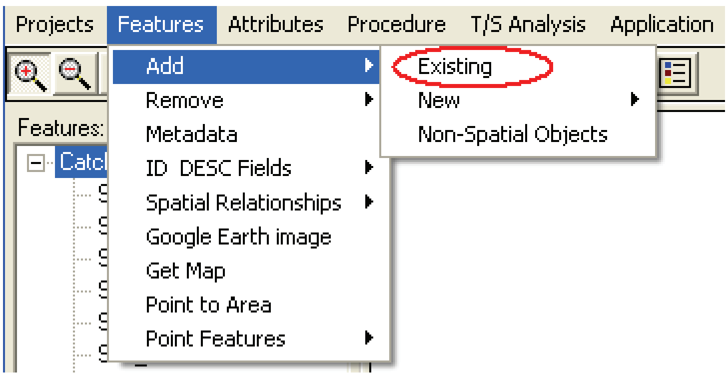


Figure 3.43 Menu selection to add an existing Feature

The Feature selection window is displayed as shown in Figure 3.44 enabling the user to select the existing Feature to be added to the display.

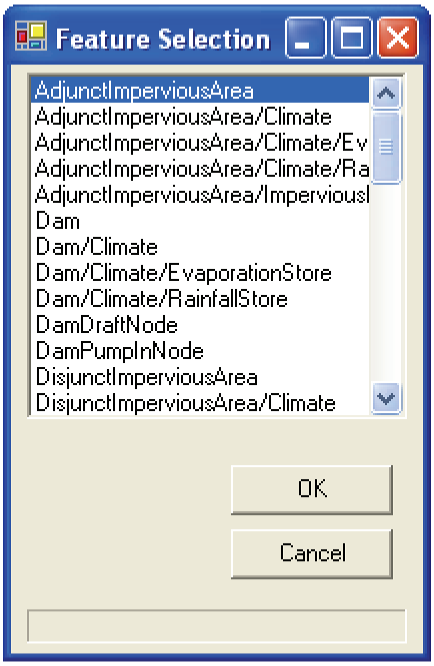


Figure 3.44 Example of the *Feature Selection* window

To hide a Feature from view first select the Feature from the Feature and Object Selector then select *Features -> Remove -> From View* from the menu as shown in Figure 3.45.

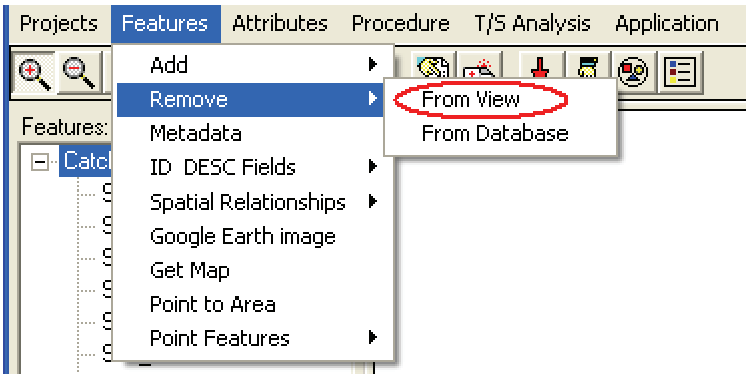


Figure 3.45 Example of menu selection to remove a Feature from view

3.3.11   How to remove an existing Feature

To remove an existing Feature from a SPATSIM-HDSF project select the Feature that needs to be removed in the Feature and Object Selector. Then select *Features -> Remove -> From Database* from the menu as shown in Figure 3.46, to remove the selected Feature from the SPATSIM-HDSF project.

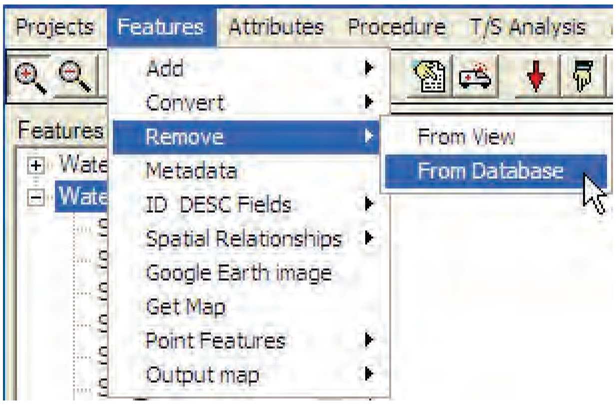


Figure 3.46 Example of menu selection to remove a Feature from the database

3.3.12 How to add metadata for a Feature

Use the Feature and Object Selector to select a Feature, and then select *Features* -> Metadata from the menu as shown in Figure 3.47.

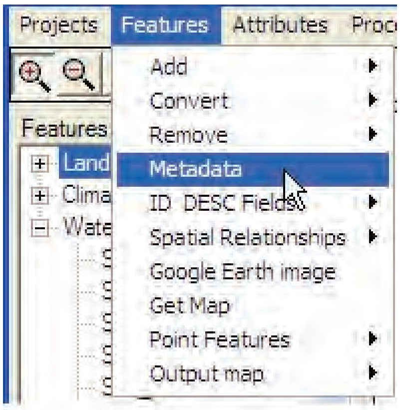


Figure 3.47 Example of menu selection to add metadata to a Feature

The *Metadata* field can contain metadata describing a Feature and may be populated and edited using The *Feature Metadata (Add/Edit*) window will then be displayed as shown in Figure 3.48 enabling the user to add or edit metadata describing the selected Feature. When finished, click on the Save button to save the changes.

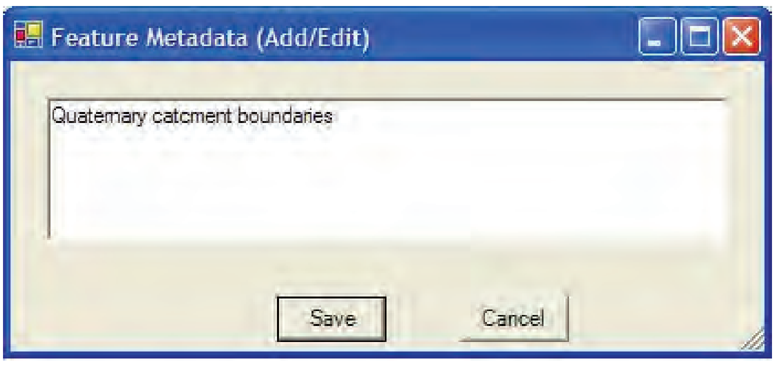


Figure 3.48 Example of Feature Metadata (Add/Edit) window

3.3.13 How to update the description field for a Feature

Select the spatial Feature that requires its description field to be updated to another field within its associated shape file. From the menu select *Features -> ID DESC Fields -> Edit Fields* as shown in Figure 3.49. The *Feature Selection* window is displayed as show in Figure 3.50. Select the field to be set as new description field then click the *Set Desc. Field* button. Finally click on the *OK* button to complete the process. The description field has now been changed.

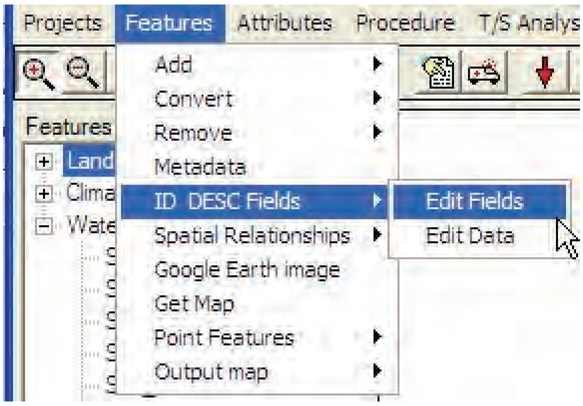


Figure 3.49 Example of menu selection to change the spatial feature description field

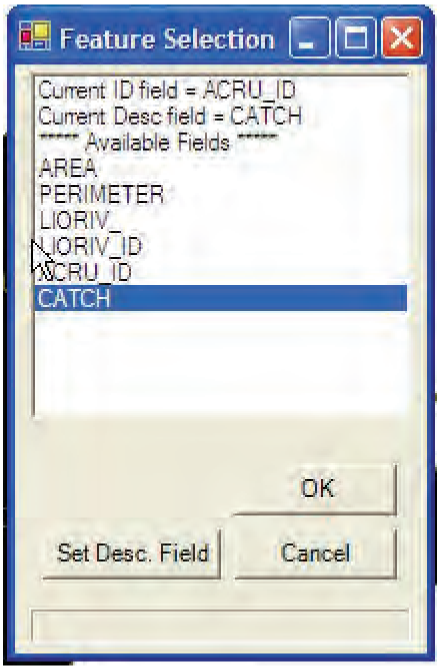


Figure 3.50 *Feature Selection* window used to update description field

3.3.14 How to edit the data in the Desc field for a Feature

Select the spatial Feature that requires the data in its description field to be edited. From the menu select *Features -> ID DESC Fields -> Edit Data* as shown in Figure 3.51. The *Editing Description Fields in a Feature* window is displayed as show in Figure 3.52. The description can be edited for each Object by clicking on the description that needs to be changed. Once the changes have been made click on the *Save To Feature* button. The description field has now been edited.

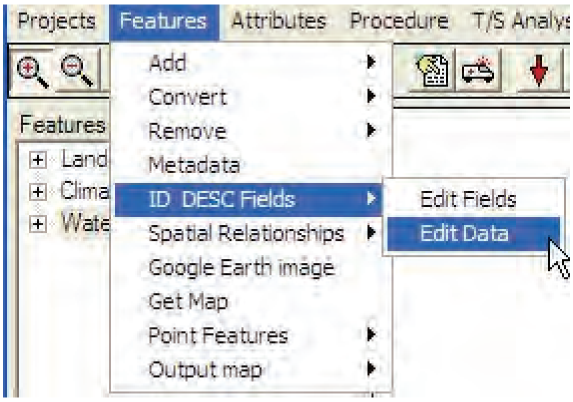


Figure 3.51 Example of menu selection to edit data in the description field of a spatial Feature

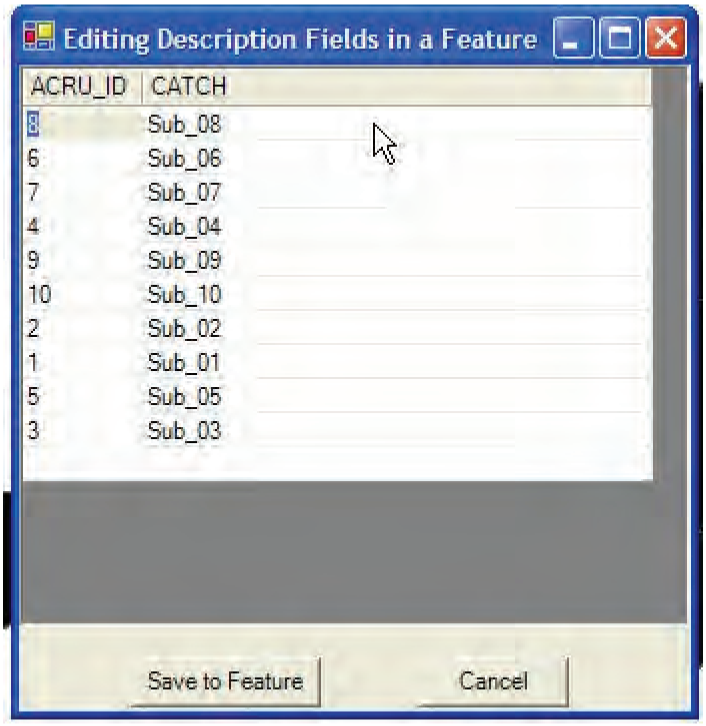


Figure 3.52 Example of the Editing Description Fields in a Feature window

3.3.15 How to setup Themes for a Spatial Feature

The legend display button as shown in Figure 3.53 is used to toggle the legend display control on and off so that the map display area can be maximised when required. One or more themes may be set up for each spatial Feature in a SPATSIM-HDSF database. To add, edit or remove a theme for a spatial Feature, first select the Feature in the Feature and Object Selector, then right-click the mouse and select the *Edit Theme* command to display the *Edit Themes* window. An example of the *Edit Themes* window is shown in Figure 3.54. The *Edit Themes* window enables themes to be added, edited or removed for the selected spatial Feature. For each theme a name, type and data source may be specified. The three options for theme type are: *SingleSymbol*, *ValueMap* and *ClassBreak*. The data source for a theme is specified by selecting an Attribute Group and then an Attribute belonging to the selected Feature. Data sources include SPATSIM-HDSF database Attributes with *TextData, IntegerData RealData or ArrayData* data types. Each theme may include one or more symbols, and these symbols may be edited by using the mouse to double-click on an existing symbol to display the *Symbol Properties* window, an example of which is shown in Figure 3.55. The *Symbol Properties* window enables a name, value, style, size, colour and outline colour to be set for the selected theme symbol.

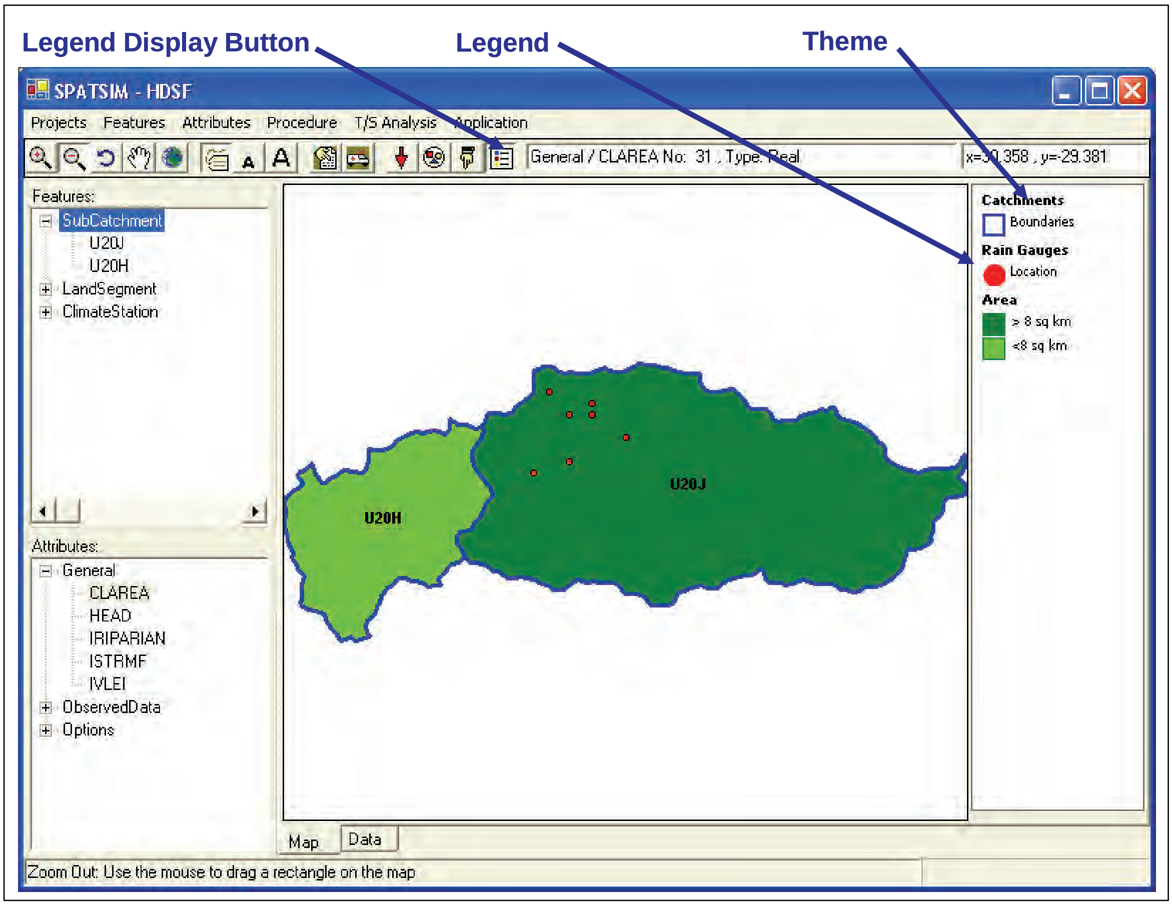


Figure 3.53 Example of the SPATSIM-HDSF user interface with the legend displayed

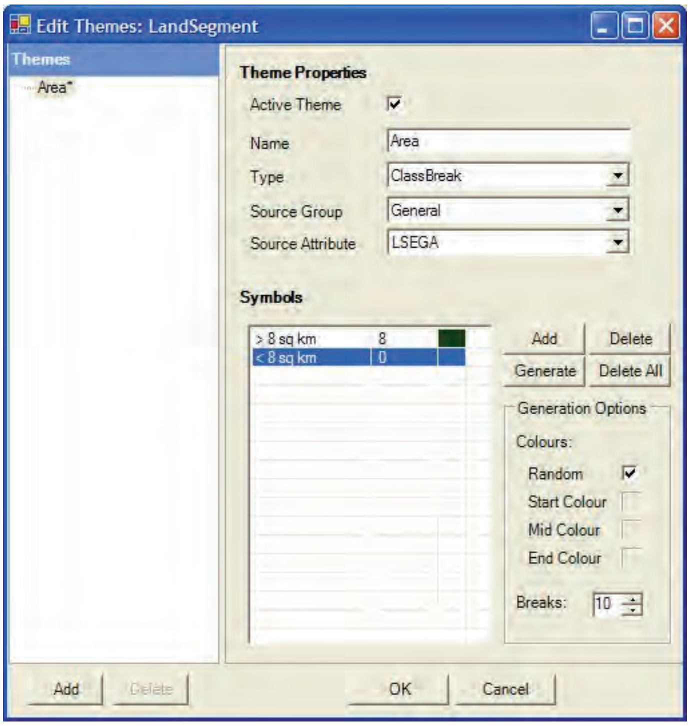


Figure 3.54 Example of the Edit Themes window

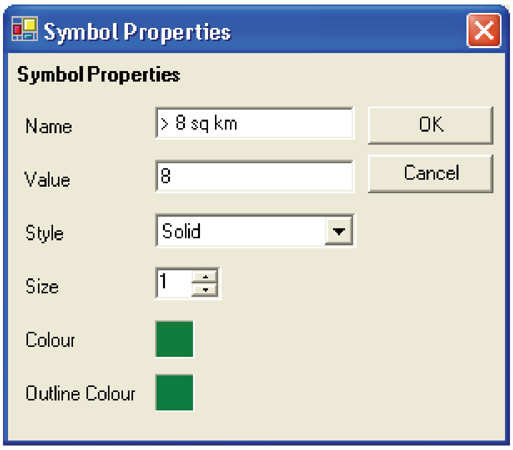
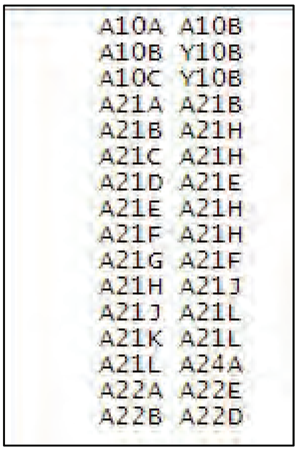


Figure 3.55 Example of the Symbol Properties window

3.3.16 How to store Downstream Spatial Relationships in an Attribute

The downstream spatial *object* of a spatial object within a feature can be defined by storing the downstream spatial object's *Desc. Field* value in any *TextData* attribute chosen to store this information. A text file is required to create the spatial relationships. Each line of this text file should contain two items, the *Desc. Field* value of a spatial Object and the *Desc. Field* value of the next downstream spatial Object. An example of this file is shown in Figure 3.56. Select the Feature and the *TextData* Attribute in the navigation panel. Select *Features->Spatial Relationships->Create Downstream Set* and then select the text file to create the downstream set.



A10A	A10B
A10B	Y10B
A10C	Y10B
A21A	A21B
A21B	A21H
A21C	A21H
A21D	A21E
A21E	A21H
A21F	A21H
A21G	A21F
A21H	A21J
A21J	A21L
A21K	A21L
A21L	A24A
A22A	A22E
A22B	A22D

Figure 3.56 Example format of text file to create spatial relationships

3.3.17 How to work with Google Earth images

A Google Earth image is required to complete this task, this can be generated via Google Earth if this is installed on your computer. The following is a procedure for preparing a Google Earth image so that it can be added as an image Feature to SPATSIM-HDSF:

- From the main menu select *Features->Google Earth image* as shown in Figure 3.57.
- The *Create Google Image Worldfile* window is displayed as shown in Figure 3.58.
- Click on *LoadImage* to select the Google Earth image. The Google Earth image will then be displayed in the *Create Google Image Worldfile* window.
- Next the top left and bottom right co-ordinates need to be selected. Click the *Top Left* button then select the top left point on the image. Click the *Bottom Right* button and then select the bottom right point on the image.
- Click on *Create World* and this will result in the worldfile (.jpw) being created in the same directory as the Google Earth image.
- The next step would be to load the Google Earth image as an image Feature. This is explained in Section 3.3.7.

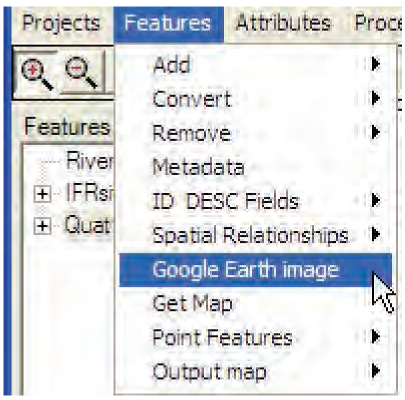


Figure 3.57 Example showing menu selection of the Google Earth image command

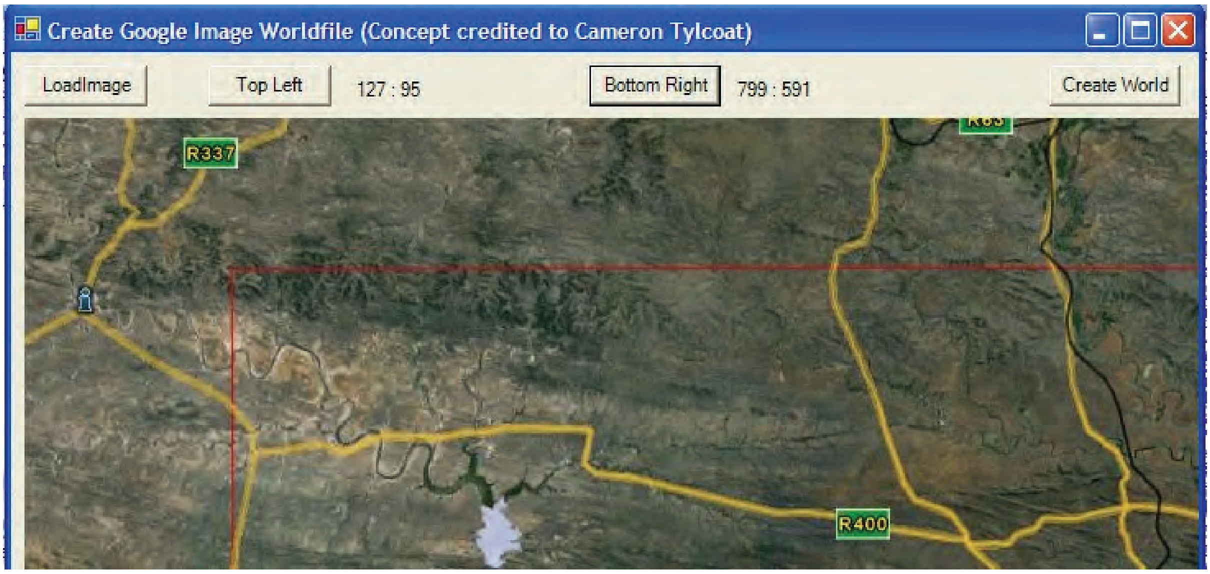


Figure 3.58 Example of the Create Google Image Worldfile window

3.3.18 How to use the Get Map tool

The *Get Map* tool in SPATSIM-HDSF can be used to load images with their correct worldfile (.jpw) files, specifically images representing maps of an area. First select a spatial Feature in the Feature and Object Selector then select *Features->Get Map* from the menu as shown in Figure 3.59. Select an Object on the M*ap* tabbed page of a spatial Feature to load an image associated with the Object. If an image file is found then the image is added as an image Feature as shown in Figure 3.60.

Note the name of the image file should start with the Object description. For example if the Object is ‘A10A’ then the image name should be ‘A10A*.jpg’ where ‘*’ refers to any 1 or more alphanumeric characters. In addition the image with its worldfile (.jpw) file should be located within the *cover* directory of the project directory.

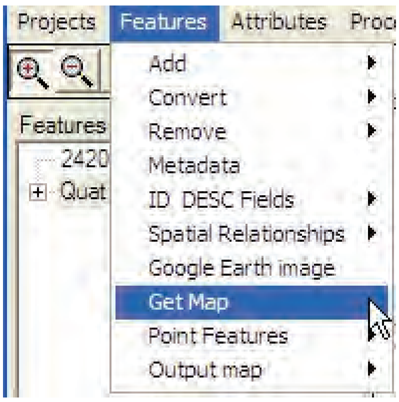


Figure 3.59 Selecting the Get Map tool from the menu

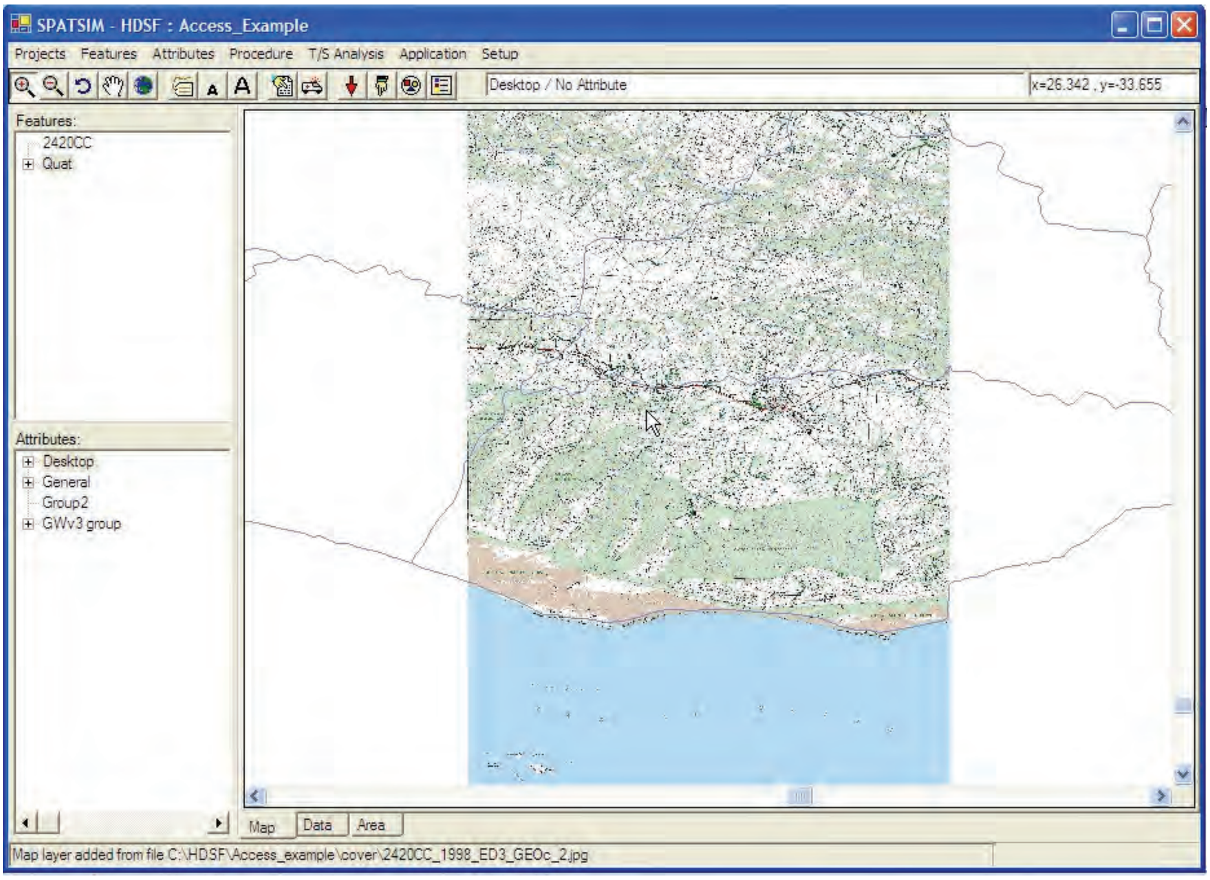


Figure 3.60 Example of an image map loaded using the Get Map tool

3.3.19 How to use the Point To Area tool

This is a SPATSIM-HDSF tool that allows the user to generate area averages from point data. Its main application is for the determination of weighted catchment average rainfall from coverages of point rainfall.

The tool to generate area averages from point data is illustrated in Figure 3.61 and is more fully described in the online SPATSIM-HDSF help (http://www.ru.ac.za/static/institutes/iwr/software/reserve/helpdss/sp_frame.htm).

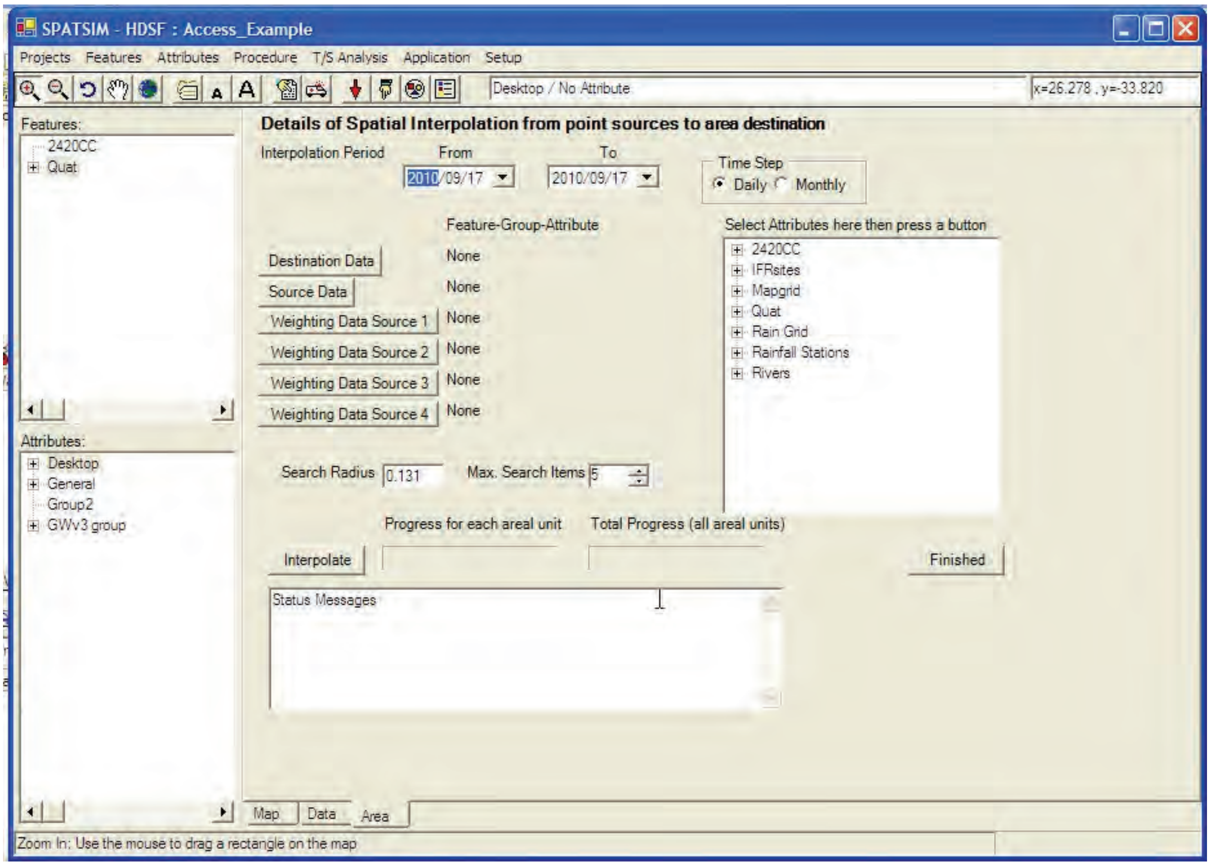


Figure 3.61 Example of the Point to Area tool

3.3.20 How to add a Point to a Point Feature

First select a spatial point Feature from the Feature and Object Selector. Next select *Features -> Point Features -> Add Points* from the menu as shown in Figure 3.62.

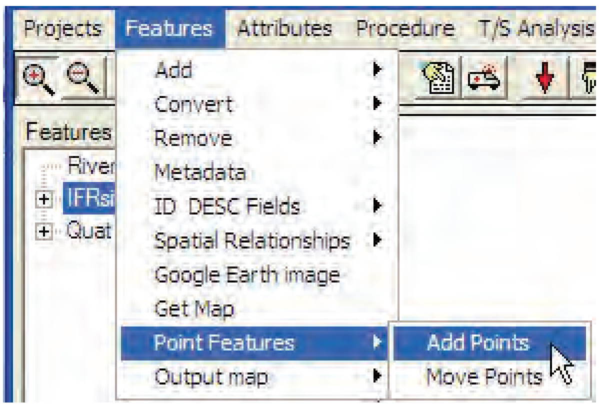


Figure 3.62 Selecting the Add Points command from the menu

The *Add a Point* window will be displayed as shown in Figure 3.63, enabling the user to enter a name for the new point. The name of the new point should be unique within the feature and should not contain any spaces. If it does the spaces are removed from the name. Once a name has been entered click on the *OK* button. The user then needs to click at the location for the new point on the map in *Map* tabbed page for the new point to be created.

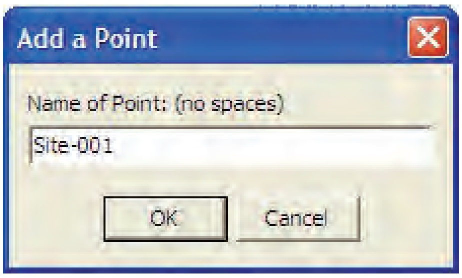


Figure 3.63 Example of the Add a Point window

3.3.21 How to move a Point in a Point Feature

This section describes the process of moving a point currently at an incorrect location on a map to the correct location on a map. First select a spatial point Feature from the Feature and Object Selector and then select the Object or point to be moved also from the Feature and Object Selector. Next select *Features -> Point Features -> Move Points* from the menu as shown in Figure 3.64. The user then needs to click at the new location on the map in *Map* tabbed page for the selected Object or point to be moved to.

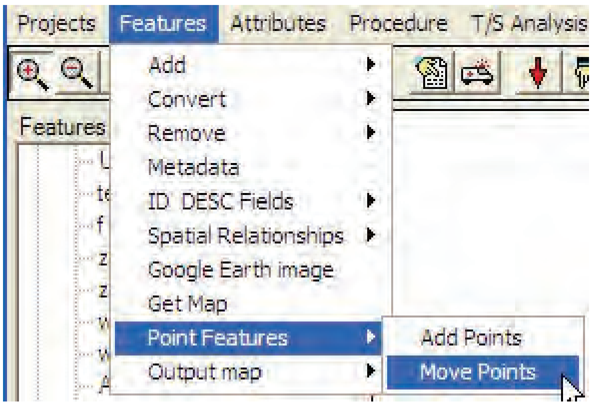


Figure 3.64 Selecting the Move a Point command from the menu

3.3.22 How to add an Attribute Group to a Feature

The following describes the steps to add an Attribute Group to a Feature.

- From the menu select *Attributes -> Manage Groups/Attributes* as shown in Figure 3.65.
- The *Add Attribute* window will be displayed as shown in Figure 3.66.

- In the Add Attribute window select the Add option within the Group/Attribute Management Options area.
- In the *Feature* dropdown list, select the Feature to which you would like to add the new Attribute Group.
- Click on the *Add Group* button next to the *Attribute Group* dropdown list. The *Add Group for Feature* window as shown in Figure 3.67 will be displayed, enabling the user to enter a name for the new Attribute Group.
- After a name has been entered for the new Attribute Group, click on the *OK* button to complete the process.
- Click on the *Close* button to close the *Add Attribute* window.

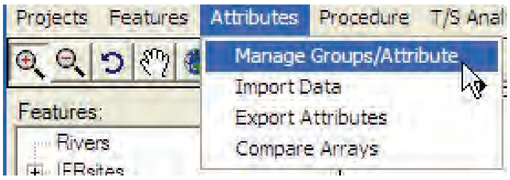


Figure 3.65 Selecting the *Manage Groups/Attributes* command in the menu

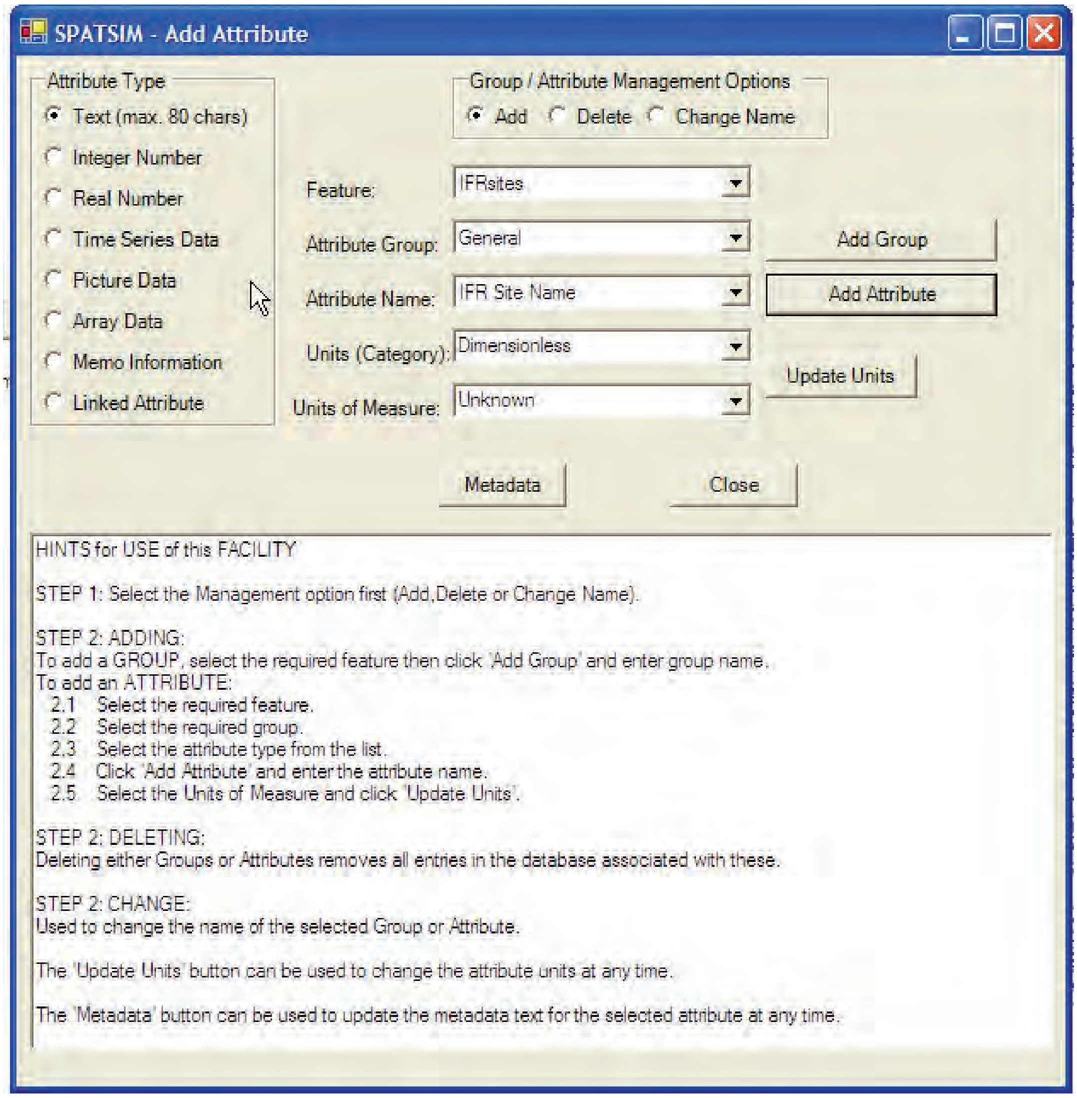


Figure 3.66 Example of the *Add Attribute* window

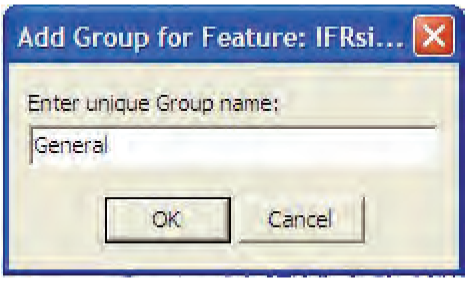


Figure 3.67 Example of the window used to enter the new Attribute Group name

3.3.23 How to rename an Attribute Group

The following describes the steps to rename an Attribute Group.

- From the menu select *Attributes -> Manage Attributes* as shown in Figure 3.65.
- The *Add Attribute* window will be displayed as shown in Figure 3.68. In the *Add Attribute* window select the *Change Name* option within the *Group/Attribute Management Options* area. Notice the *Add Group* button has now been changed to *Change Group Name* in the *Add Attribute* window.
- In the *Feature* dropdown list select the Feature containing the Attribute Group for which the name is to be changed.
- Click on the *Change Group Name* button next to the *Attribute Group* dropdown list. The Change Group Name window will be displayed as shown in Figure 3.69, enabling the user to enter a new Attribute Group name to be entered in place of the current name.
- After a new Attribute Group new Attribute Group name has been entered click on the *OK* button to complete the process.
- Click on the *Close* button to close the *Add Attribute* window.

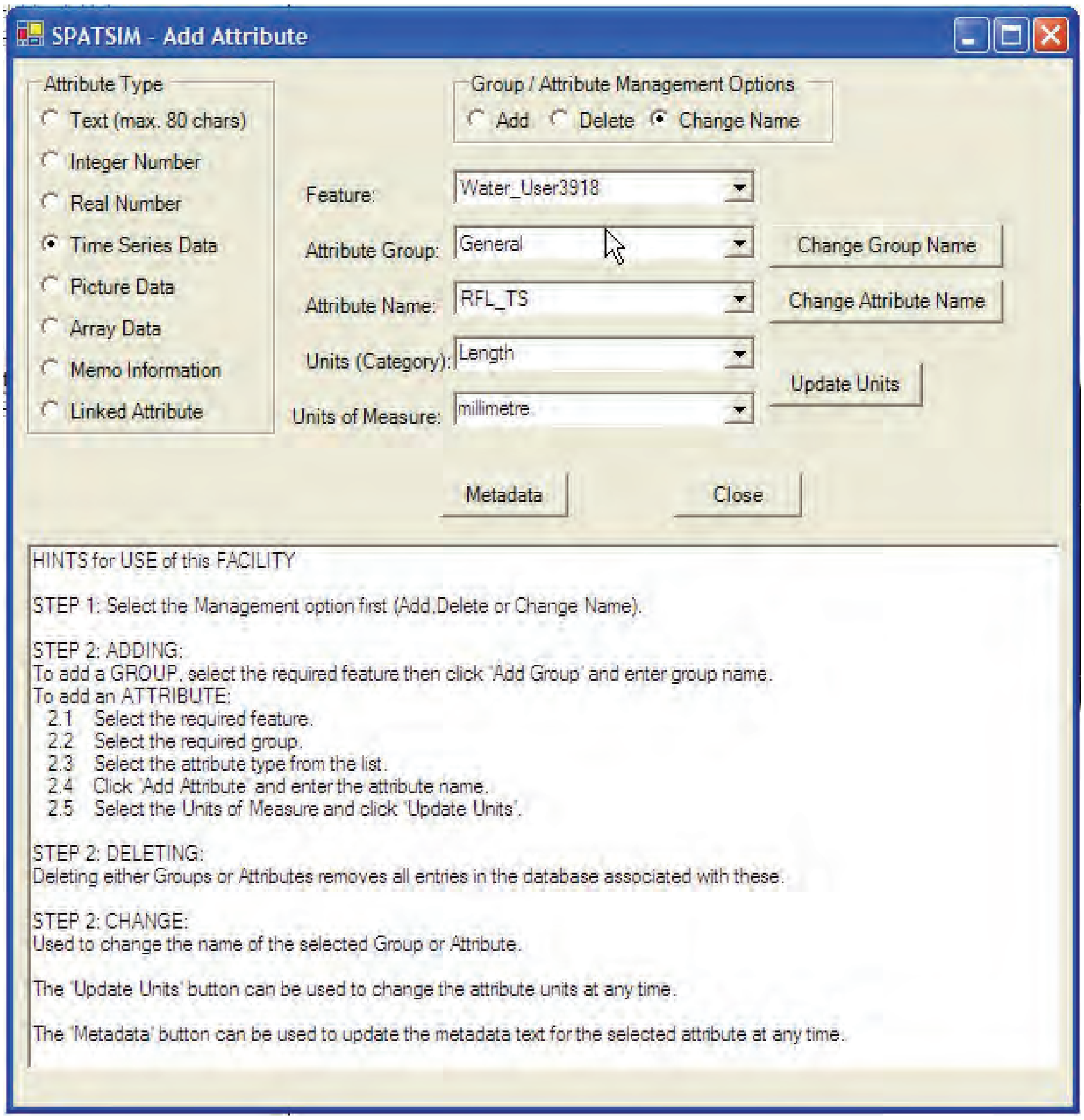


Figure 3.68 The *Add Attribute* window with the *Change Name* option selected

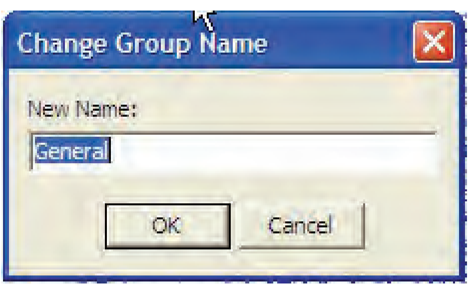


Figure 3.69 The window used to enter new Attribute Group name

3.3.24 How to delete an Attribute Group

The following describes the steps to delete an Attribute Group.

- Select *Attribute -> Manage Attributes* from the menu as shown in Figure 3.65.
- The *Add Attribute* window will be displayed as shown in Figure 3.70. In the *Add Attribute* window select the *Delete* option within the *Group/Attribute*

Management Options area. Notice the *Add Group* button has now been changed to *Delete Group.*

- In the *Feature* dropdown list select the Feature containing the Attribute Group to be deleted.
- Select the Attribute Group to be deleted from the *Attribute Group* dropdown list.
- Click on the *Delete Group* button next to the *Attribute Group* dropdown list. This will delete the Attribute Group that was selected in the *Attribute Group* dropdown list. Note, deleting an Attribute Group will also delete all the Attributes and associated data belonging to that Attribute Group from the database.
- Click on the *Close* button to close the *Add Attribute* window.

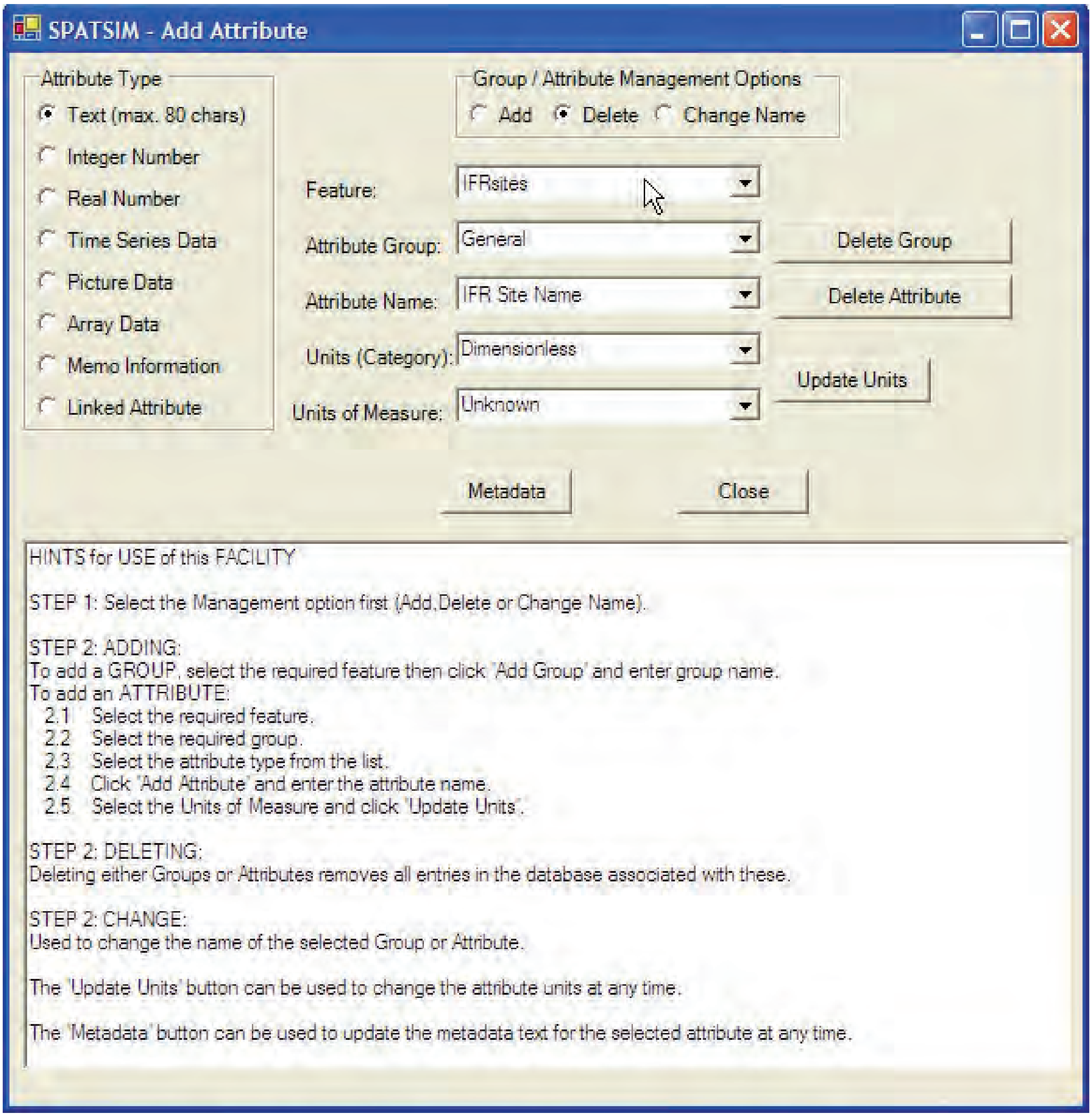


Figure 3.70 The *Add Attribute* window with the *Delete* option selected

3.3.25 How to add an Attribute to a Feature

The following describes the steps to add an Attribute to a Feature.

Figure 3.71

- Select *Attribute* -> *Manage Attributes* from the menu as shown in Figure 3.65.
- The *Add Attribute* window will be displayed as shown in Figure 3.71. In the *Add Attribute* window select the *Add* option within the *Group/Attribute Management Options* area.
- The Attribute type needs to be specified for the new Attribute by choosing an option in the *Attribute Type* section.
- In the *Feature* dropdown list select the Feature to which the new Attribute is to be added.
- In the *Attribute Group* dropdown list select the Attribute Group to which the new Attribute is to be added.
- Click on the *Add Attribute* button, and a confirmation dialog window will be displayed requesting confirmation that an Attribute of the selected Attribute type is to be created. Click on the *Yes* button and a window will appear as shown Figure 3.72 enabling the name of the new Attribute to be entered.
- After entering the new Attribute name, click on the *OK* button. This will result in the new Attribute being created and displayed in the *Attribute Name* dropdown list.
- If a *Time Series Data*, *Integer Data* or *Real Data* Attribute type is selected then a unit of measure may be specified by selecting a unit of measure from the *Units of Measure* dropdown list and then selecting the *Update Units* button to save the selected unit of measure.
- For other Attribute types a default dimensionless unit of measure is automatically assigned to the Attribute.
- Click on the *Close* button to close the *Add Attribute* window.

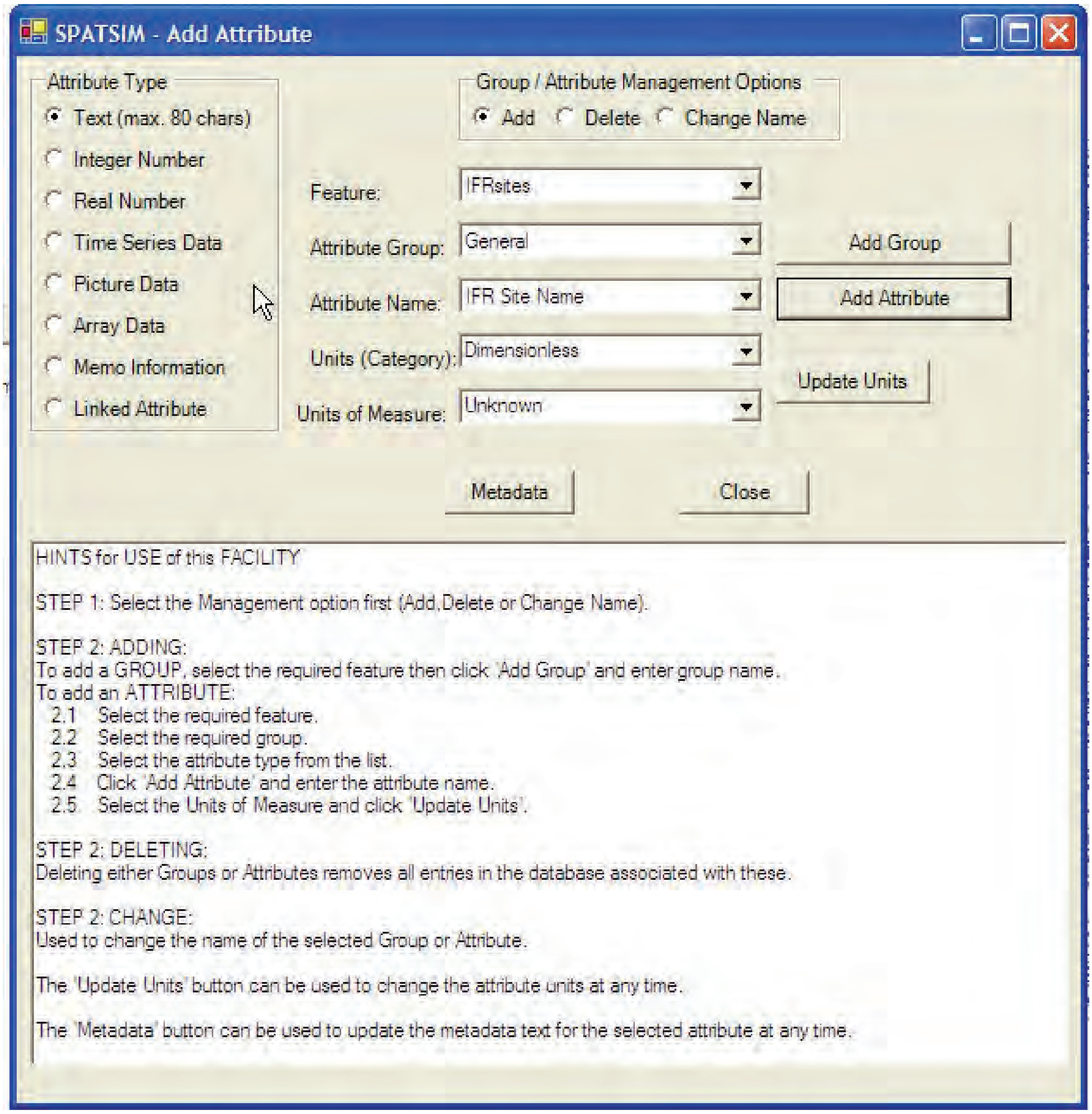


Figure 3.71 Example of the *Add Attribute* window

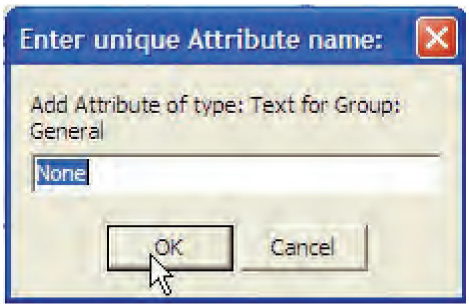


Figure 3.72 The window used to enter the name of a new Attribute

3.3.26 How to rename an Attribute

The following describes how to rename an Attribute.

- Select *Attribute -> Manage Attributes* from the menu as shown in Figure 3.65.
- The *Add Attribute* window will be displayed as shown in Figure 3.73. In the *Add Attribute* window select the *Change Name* option within the *Group/Attribute Management Options* area. Notice the *Add Attribute* button has now been changed to *Change Attribute Name* in the *Add Attribute* window*.*
- In the *Feature* dropdown list select the Feature containing the Attribute to be renamed.
- In the *Attribute Group* dropdown list select the Attribute Group containing the Attribute to be renamed.
- Click on the *Change Attribute Name* button next to the *Attribute Name* dropdown list. A window showing the current Attribute name will be displayed as shown in Figure 3.74, enabling the user to enter a new Attribute name. After a new Attribute name has been entered click on the *OK* button to complete the process.
- Click on the *Close* button to close the *Add Attribute* window.

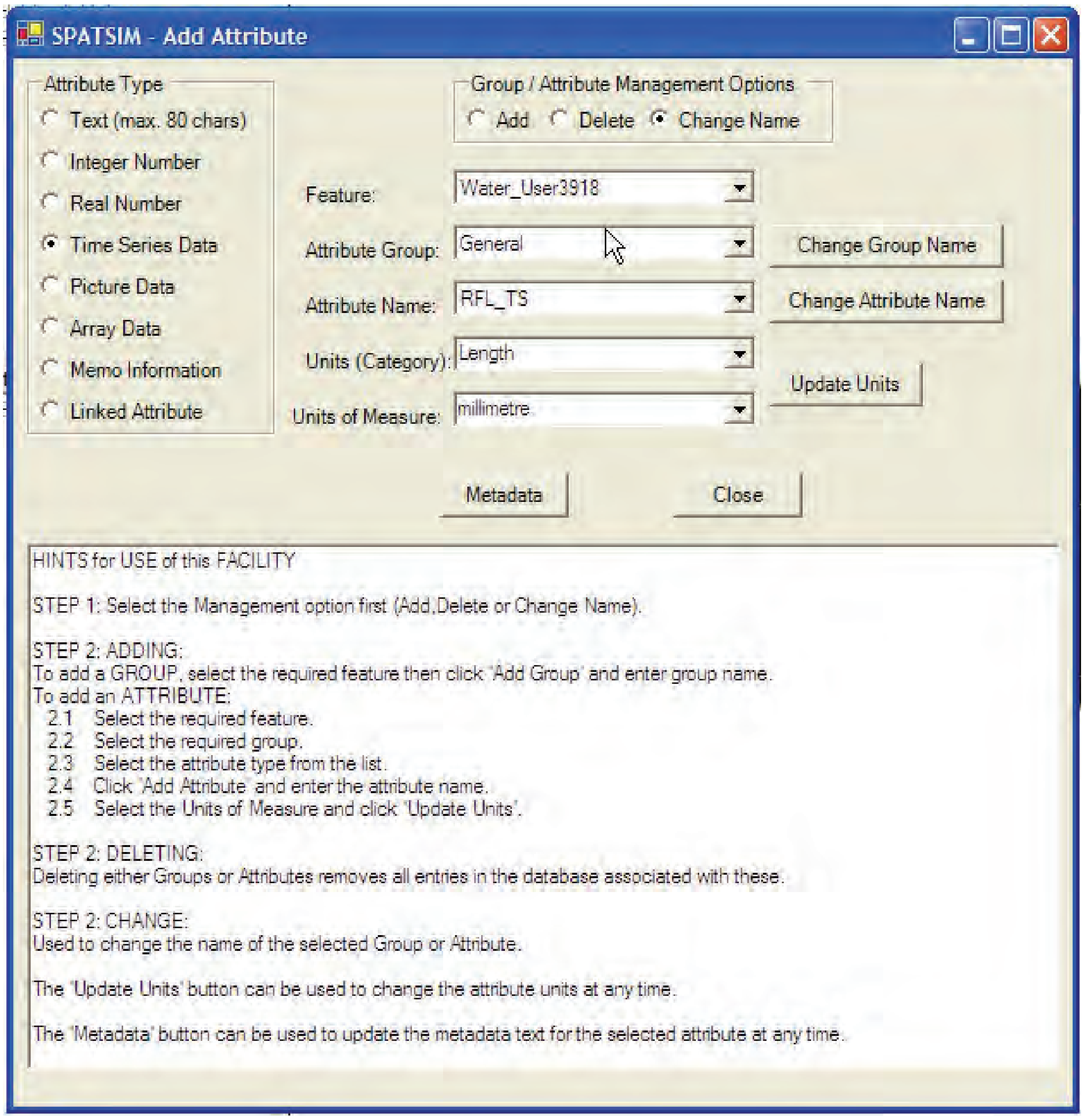


Figure 3.73 The *Add Attribute* window with the *Change Name* option selected

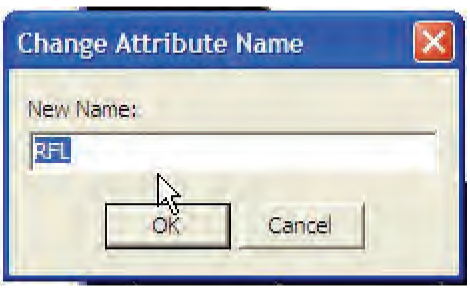


Figure 3.74 The window used to enter new Attribute name

3.3.27 How to delete an Attribute

The following describes how to delete an Attribute.

- Select *Attribute* -> *Manage Attributes* from the menu as shown in Figure 3.65.
- The *Add Attribute* window will be displayed as shown in Figure 3.75. In the *Add Attribute* window select the *Delete* option within the *Group/Attribute Management Options* area. Notice the *Add Attribute* button has now been changed to *Delete Attribute.*
- In the *Feature* dropdown list select the Feature containing the Attribute to be deleted
- In the *Attribute Group* dropdown list select the Attribute Group containing the Attribute to be deleted.
- In the *Attribute Name* dropdown list select the Attribute to be deleted.
- Click on the *Delete Attribute* button next to the *Attribute Name* dropdown list. This will delete the Attribute and all the associated data belonging to that Attribute from the database.
- Click on the *Close* button to close the *Add Attribute* window.

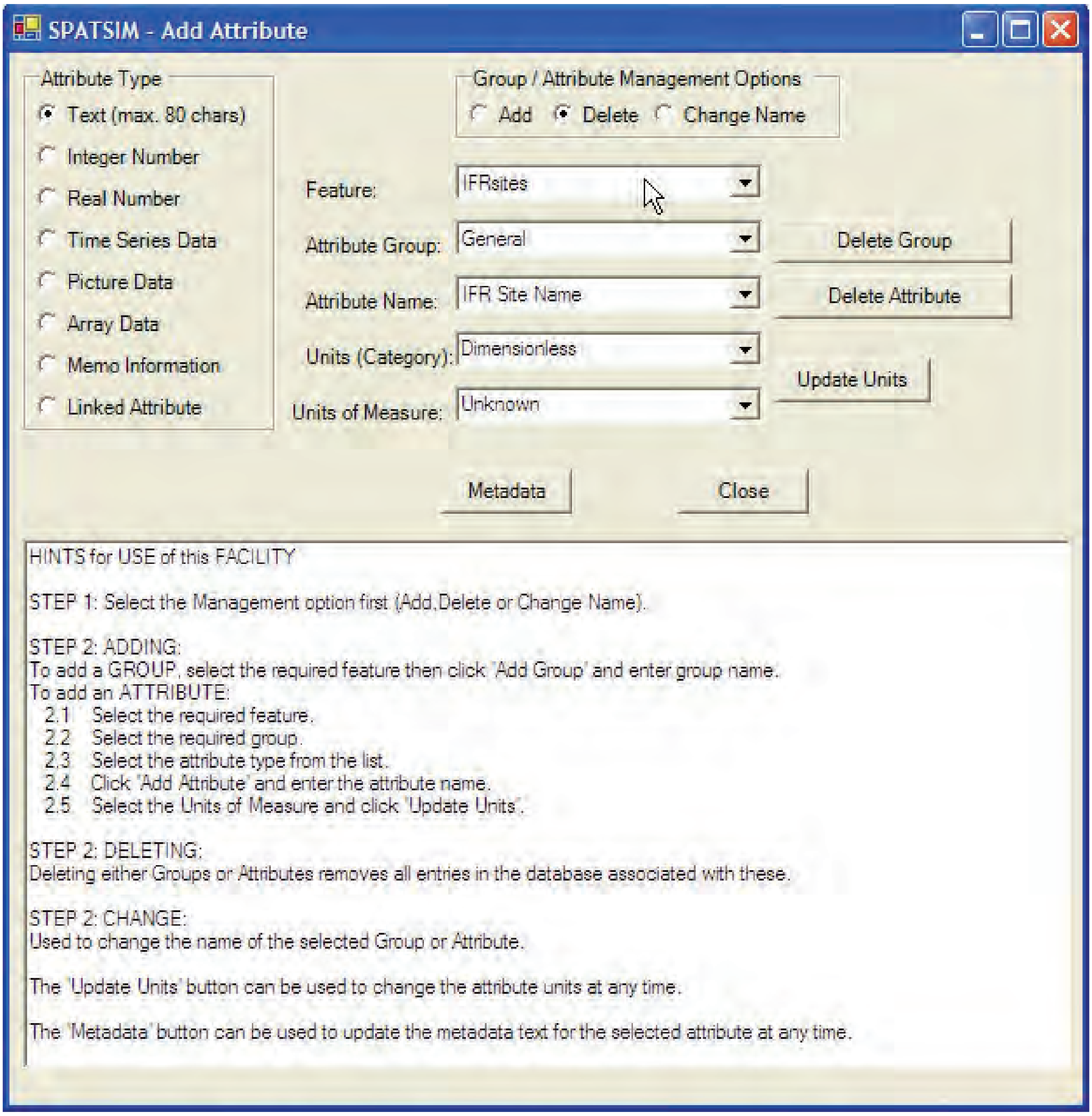


Figure 3.75 The *Add Attribute* window with the *Delete* option selected

3.3.28 How to add metadata to an Attribute of a Feature

The following describes how to add or edit metadata for an Attribute.

- Select *Attribute -> Manage Attributes* from the menu to display the *Add Attribute* window.
- Use the *Feature*, *Attribute Group* and *Attribute Name* dropdown lists to select the Attribute for which metadata is to be added or edited.
- Click on the Metadata button to display the *Attribute Metadata (Add/Edit)* window shown in Figure 3.76.

- In the *Attribute Metadata (Add/Edit)* window add or edit the Attribute metadata as required and then click on the *Save* button to complete the process..

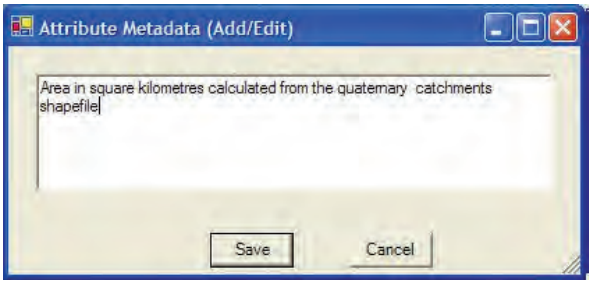
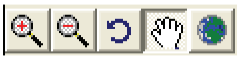


Figure 3.76 Example of the *Attribute Metadata (Add/Edit)* window

3.3.29 How to use the Map toolbar

The toolbar contains buttons used to interact with the Map View and includes navigation tools, labelling tools and spatial Feature Object selection tools.

Navigation Tools 

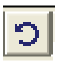
The toolbar is grouped into sections, the first of these is for navigating within the Map View.

Zoom In 

Select the *Zoom In* button. Then move the cursor over the map to where you want zoom in then click and drag the mouse to draw a rectangle indicating the new map window extent.

Zoom Out 

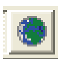
Select the *Zoom Out* button. Then as for *Zoom In* click and drag the mouse pointer to draw a rectangle within the map window to zoom out.

Zoom to previous extent 

This toolbar button is useful in that it is a quick shortcut to navigate to previously zoomed in sections of the map. It can be pressed numerous times to move quickly to previously selected Map View extents.

Pan Tool 

This enables the pan of a map that has been zoomed in. If the map is at its full extent the pan tool will not work, as the map is in full view.

Full Extent 

This button will return the Map View to display the full map Feature.

Labelling Tools

The second section on the toolbar is for displaying labels within the Map View. These tools apply to the currently selected spatial map Feature.

Add/Remove Labels

This is a toggle button to switch on and off the labels for the selected spatial Feature displayed in the Map View.

Decrease Label Size and *Increase Label Size*

If labels have been added to the Map View for the selected spatial Feature these labels can be resized by pressing these buttons. They can be pressed numerous times to achieve the desired font size. If the labels are removed by pressing the *Add/Remove Labels* button then added again the label font size is reset.

Additional Tools

Show Attribute Data

This button opens the attribute editing forms and displays the attribute data associated with the feature object selected in the *Feature and Object Selector* and the attribute selected from the *Attribute Group and Attribute Selector* within the main interface of SPATSIM-HDSF.

Check Database Integrity

This button checks the database integrity of the database of the associated project currently open within the main interface of SPATSIM-HDSF.

Select one or more spatial elements

This button enables the selection of one or more spatial elements to perform certain operations provided by the SPATSIM-HDSF, such as running models and comparing array data.

Select upstream subareas

The selected upstream subareas of a feature object such as a catchment can be selected by selecting the feature object and then clicking on this *Select upstream subareas* button.

Select downstream subareas

The selected downstream subareas of a feature object such as a catchment can be selected by selecting the feature object and then clicking on this *Select downstream subareas* button.

Hide/Show the map legend

This button hides or shows the legend of the currently selected spatial feature in the *Feature and Object Selector* of the main interface of SPATSIM-HDSF.

3.3.30 How to select Spatial Feature Objects on a Map

There will be instances were single or multiple objects need to be selected to carry out certain tasks in SPATSIM-HDSF. An example would be to compare array values between different objects. The *Map* tabbed page needs to be visible. Click on the *Select one or more spatial elements* button from the toolbar, as highlighted in Figure 3.77. A list box will appear over the *Map* tabbed page. Click on objects on the map to add these objects to the list box as shown in Figure 3.77. Multiple objects can be added to this list box if needed.

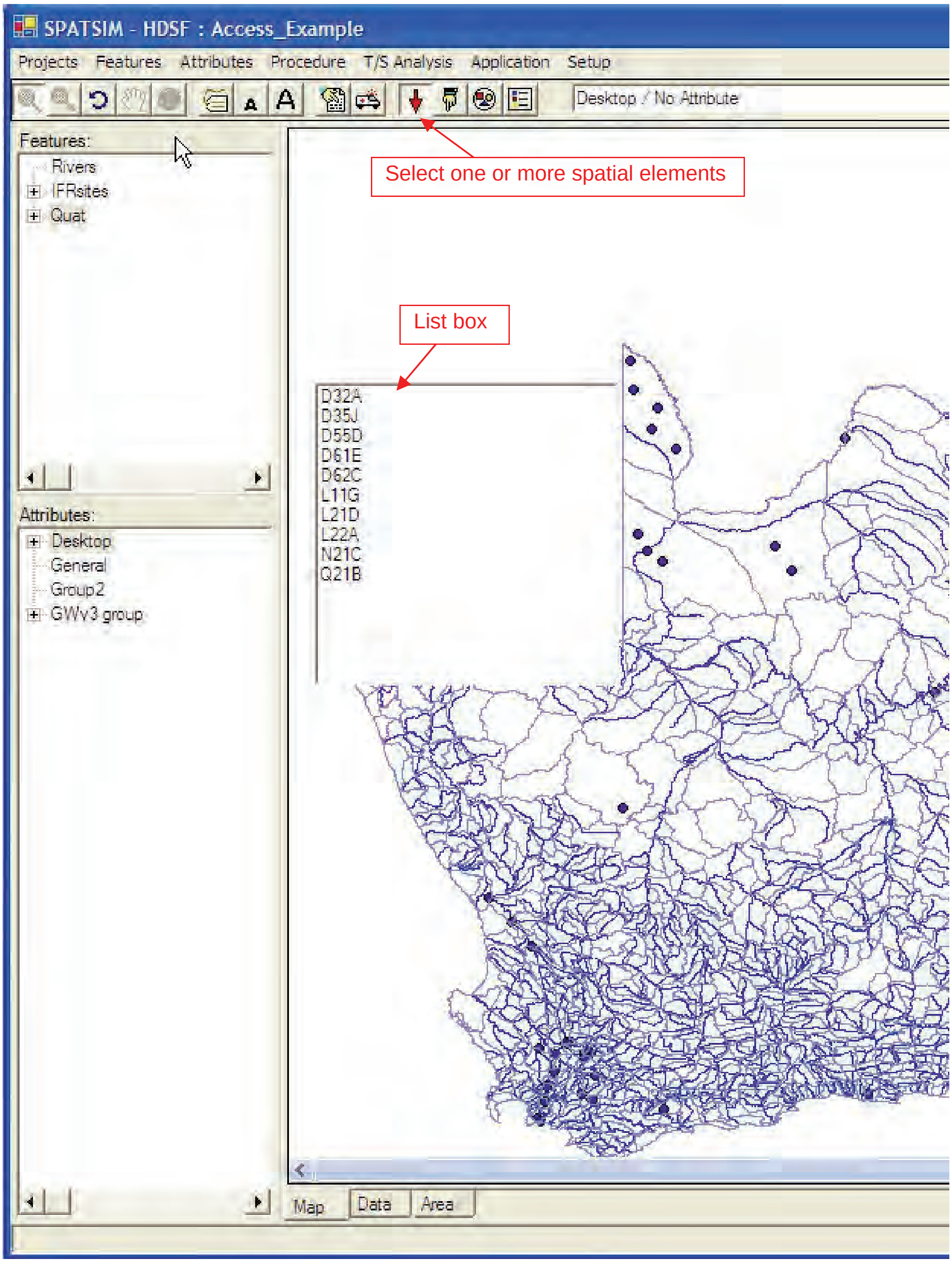


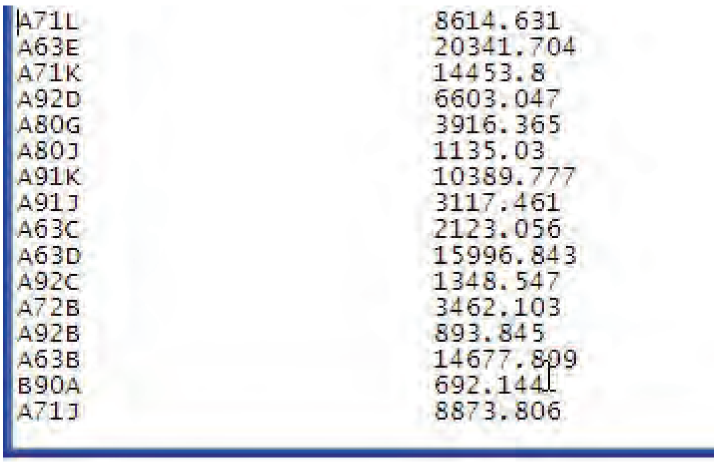
Figure 3.77 Example showing selection of spatial Feature objects on the *Map* tabbed page

3.3.31 How to import data into the Database

This section describes the various methods available to import data into a SPATSIM-HDSF project database.

Importing Text, Integer and Real Attribute data from text files

Text, Integer and Real type data may be imported from a text file into an Attribute in SPATSIM-HDSF. The text file should contain two columns separated by a space. The first column should contain the exact descriptions of existing objects in the selected spatial/non-spatial Feature. The second column should contain the text, integer or real data to be added to the Attribute selected for the Feature. An example of the text file format is shown in Figure 3.78.



A71L	8614.631
A63E	20341.704
A71K	14453.8
A92D	6603.047
A80G	3916.365
A80J	1135.03
A91K	10389.777
A91J	3117.461
A63C	2123.056
A63D	15996.843
A92C	1348.547
A72B	3462.103
A92B	893.845
A63B	14677.809
B90A	692.144
A71J	8873.806

Figure 3.78 Example of a text file containing import data

Use the Feature and Object Selector to select a Feature and then use the Attribute Group and Attribute Selector to select the Attribute for the Attribute for which data is to be imported. Select *Attributes -> Import Data -> Text Files to Text/Integer/Real* from the menu. An *Open* file dialog window will be opened enabling selection of the text file containing the data to be imported. Select the text file and click on the *Open* button to complete the data import process.

Importing text files to an Array Attribute

This option enables the user to import data from different types of text file to an array Attribute. The different file types are described as follows:

- Flat File, Rows First: This is a text file with one value per line, where the data are in the order of

row1/column1
row1/column2
row1/column3

row2/column1
row2/column2
row2/column3
.
.
.
etc.

- Flat File, Columns First: This is a text file with one value per line, where the data are in the order of

column1/row1
column1/row2
column1/row3

.
column2/row1
column2/row2
column2/row3
.
.
etc.

- Table File (Data Matrix): This is a text file with the data arranged in the same way as it appears on the screen in the Attribute display table.

col1/row1 col2/row1 col3/row1 . . etc.

col1/row2 col2/row2 col3/row2 . . etc.
.
.
etc.

If the text data file does not contain the same amount of data, that is the same number of rows and columns,, specified for the selected Attribute(for one or more spatial elements) then the data import may either fail or bring in the wrong values.

Use the Feature and Object Selector to select a Feature and then use the Attribute Group and Attribute Selector to select the Attribute for which data is to be imported. Select *Attributes -> Import Data -> Text Files to Array Attribute*. An *Open* file dialog window will be opened enabling selection of the text file containing the data to be imported. Select the text file and click on the *Open* button to complete the data import process.

Import Non-Spatial Feature Attribute data

Text, Integer or Real type data may be imported from a CSV file into an Attribute for objects within a non-spatial Feature. The following describes this import process.

- Use the Feature and Object Selector to select a non-spatial Feature and then use the Attribute Group and Attribute Selector to select a text, integer or real type Attribute.
- Select *Attributes -> Import Data -> Import Non-Spatial Feature Attribute Data* from the menu. An *Open* file dialog window will be displayed enabling the selection of a CSV file containing the data to be imported. Select a CSV file then click on the *Open* button to import data to the selected Attribute.
- The *Adding Attribute Data From Feature Attribute* window will be displayed as shown in Figure 3.79.
- In the *Description Field (Unique)* dropdown list select the column in the CSV which contains descriptions to matching the Object descriptions of the non-spatial Feature objects.
- In the *Attribute Field* dropdown list select the column in the CSV file which contains the data to be imported.
- Click on the *Import* button to import the data.

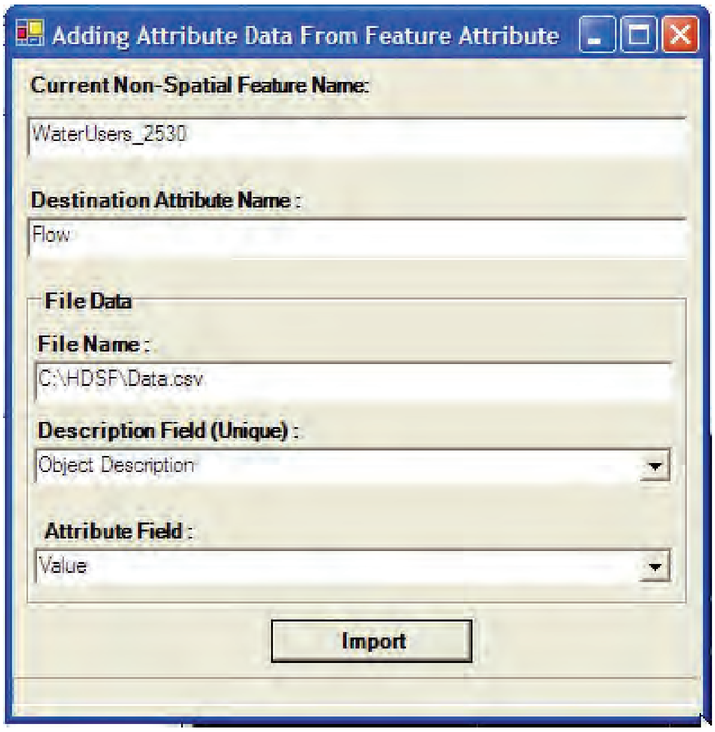


Figure 3.79 Example of the *Adding Attribute Data From Feature Attribute* window

Import data from a Spatial Feature's shapefile attribute

This import only works for Spatial Features. This section deals with the import of attribute data from a selected Feature's spatial shapefile attribute table. It can only handle text, integer and real data types. Knowledge of the data type of the attribute being imported is required to ensure the data is imported to the correct attribute defined in SPATSIM-HDSF for the Feature. This knowledge can be acquired using any GIS tool. The following describes the process of importing a Feature attribute:

- Use the Feature and Object Selector to select the spatial Feature requiring import of attribute data from its spatial attribute table.
- An Attribute associated with the Feature selected above needs to be selected to store the attribute data. If the attribute does not exist, it can be created following the steps outlined in Section 3.3.25. The attributed needs to be a text, integer or real data type based on the knowledge of the attribute data type being imported. Use the Attribute Group and Attribute Selector to select the existing or newly created Attribute.
- Select *Attributes -> Import Data -> Import from Feature Attribute* from the menu. The *Transfer data from feature to Attribute* window will be displayed as shown in Figure 3.80. Note the Feature and its associated attribute selected in the previous step is displayed in the window.
- The shapefile attributes that can be imported are listed in the *Select Feature Attribute* listbox as shown in Figure 3.80. Select the attribute to be imported from this listbox.
- Click on the *Add Attribute Data* button to import the attribute data. A progress bar will be displayed showing the import progress.
- Once the progress has completed, click on the *Finished* button to close the window.

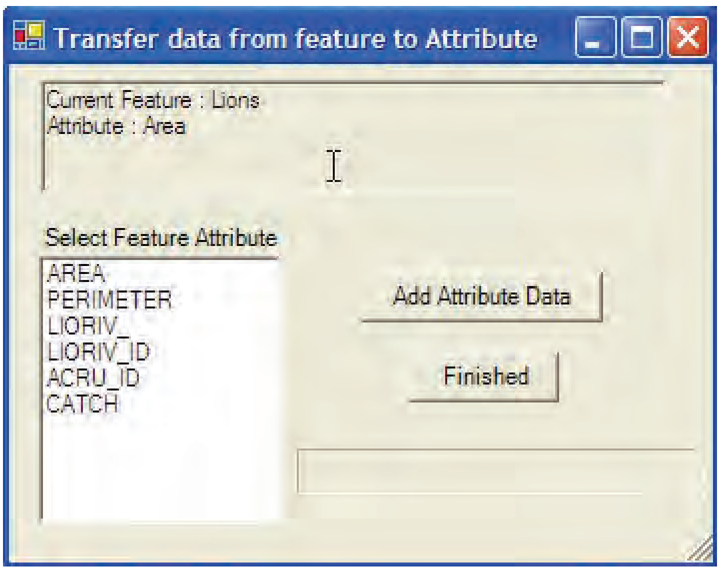


Figure 3.80 Example of the *Transfer data from feature to Attribute* window

Import T/S data

There are many different types and raw formats for time series data and a special facility exists for importing this type of data. The assumption is that the data for a single spatial element are contained within a single data file and that some window of identification (either the filename or text within the file) can be used to associate with the description field (*Desc. Field*) specified for the shape file associated with a spatial Feature. Note this functionality only works for spatial Features and does not include non-spatial Features.

The following help provides some generic information for using this facility, but the user is advised to step through the process carefully for the first few times that a specific import option (i.e. data file format) is used.

It is essential that the required Feature and a time series type Attribute are currently selected before carrying out an import of time series data. Select *Attributes -> Import Data -> Import T/S Data* from the menu as shown in Figure 3.81. The *Generic Time Series Import* window will be displayed as shown in Figure 3.82.

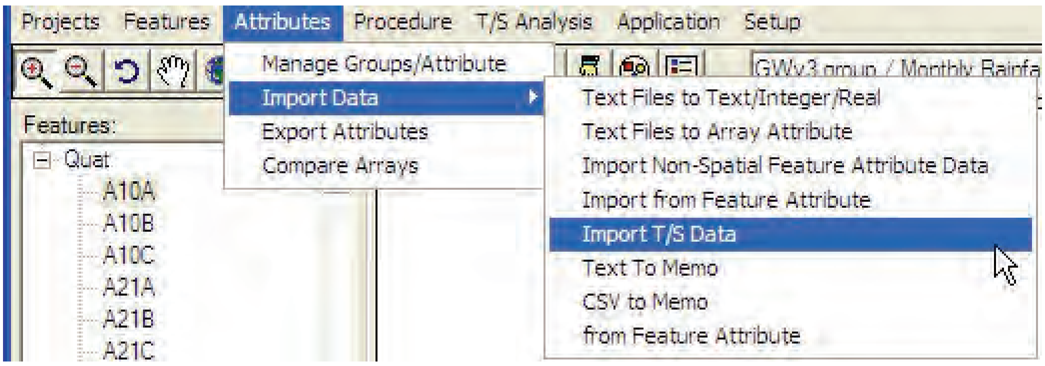


Figure 3.81 Selecting Import T/S Data

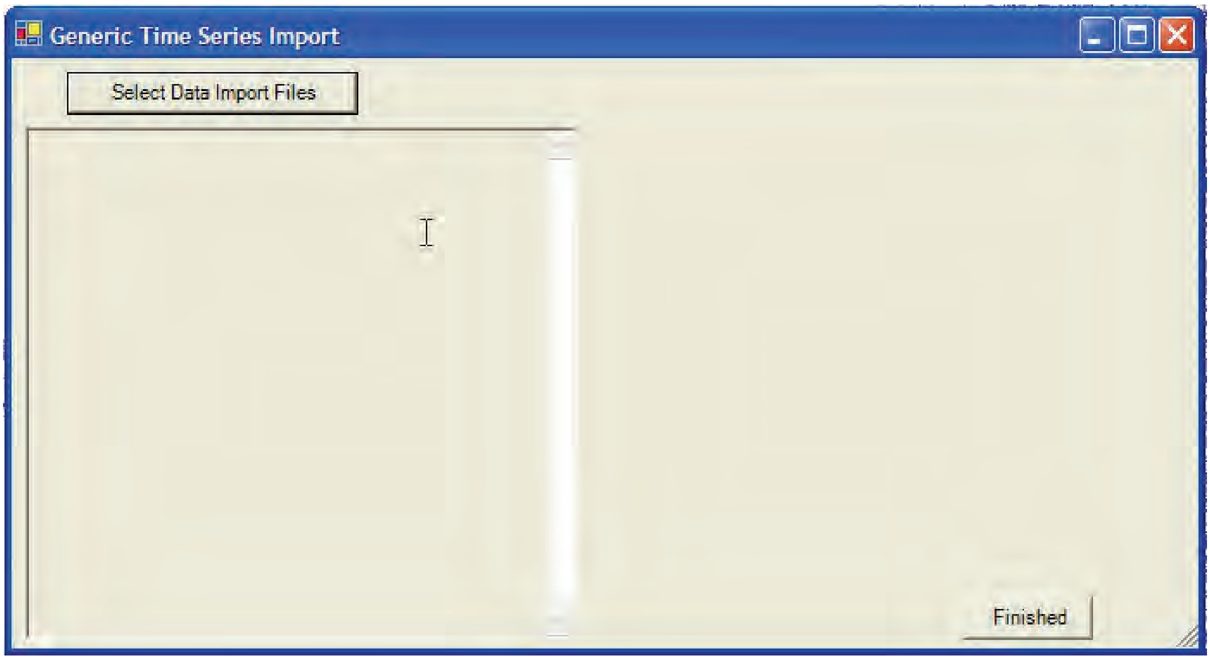


Figure 3.82 Example of the Generic Time Series Import window

The main steps are as follows.

(i) Selecting files

There are two main methods of selecting raw data files. The first is through the manual selection of all required files within a folder, which is achieved by highlighting those required in a standard Windows *Open* file dialog window. The second is through the selection of all files within a single folder. There are two sub-options in the first and second method. If a folder is selected, but no files highlighted, then all files (regardless of extension) are selected. If one file within the folder is selected, then all files with the same extension are selected.

The files that have been selected can be listed on the Data Input window shown in Figure 3.85 by right clicking on the bottom right display box.

In the *Generic Time Series Import* window click the *Select Data Import Files* button to display the *rfFileForm* window as shown in Figure 3.83. In the *rfFileForm* window select the relevant options then click the *Select Files* button which will result in an *Open* file dialog window being displayed in which the relevant files containing time series data may be selected.

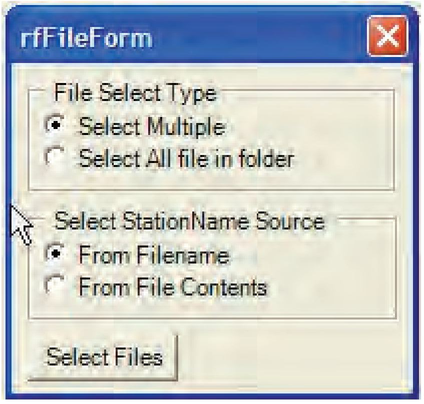


Figure 3.83 Tool to enable selection of files

(ii) Identifying data

The destination (i.e. which Feature Object to associate the data with) of the data within each raw data file is determined using the contents of the *Desc. Field* of the selected Feature. This is the Feature Objects *A10A to A21J* as shown in Figure 3.84. There are two ways in which the raw data can be identified and associated with the correct spatial element. The first of these is to use the names of the selected files. Thus data contained within a file called A10A.dat will be associated with a Feature Object whose *Desc. Field* contains the text 'A10A'. The second method is through the file content and this will only work for some of the file format options. For example, the old and new DWAF flow data formats, as well as the CCWR daily rainfall files, have the station name on each line of data. This can be used to identify the destination. Similarly, spreadsheet type files can have a station name specified on each line, if required.

 It is important to ensure that the contents of the *Desc. Field* of the Feature and the filenames (or station names in a file) are the same if this data import facility is to work.

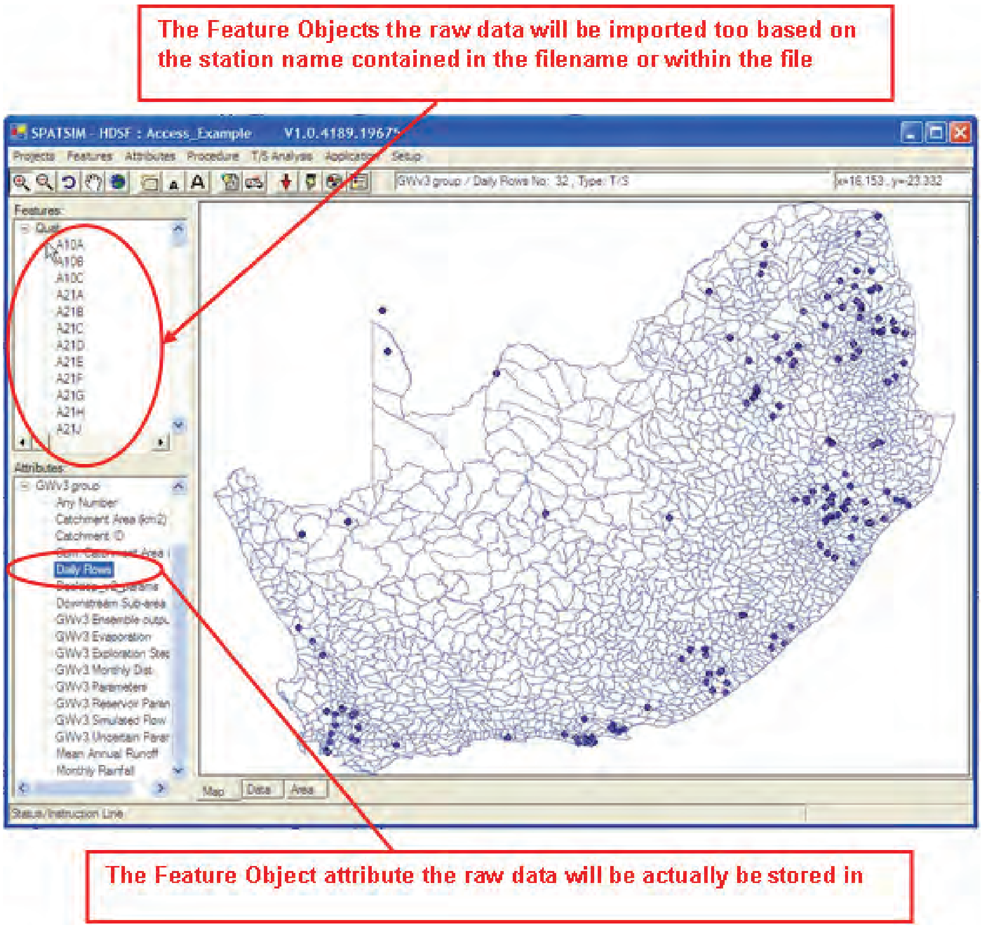


Figure 3.84 Illustration of the destination of the imported time series data within SPATSIM-HDSF

(iii) <u>Specifying the data format</u>

Having selected the files to be imported the *Data Input* window shown in Figure 3.85 will be displayed. The user is required to specify the data format and some of the options that identify how the data are stored in the file. Different file types have different options and the user must ensure that all the options are selected correctly if the data import is to proceed without error.

On the right-hand side of the *Data Input* window the upper right display box provides an example of the format of the selected data format, while the bottom right display box lists the first few lines of one of the selected files as shown in Figure 3.85. These can be used to ensure that there is a match between the selected files and the selected data format.

It should be obvious that only one format can be imported at the same time and that the options selected for that format should apply to all the files. For example, the import will fail if an attempt is made to import several spreadsheet type files, which have a different number of header lines. Similarly, mixing DWAF flow files that have station names included in each line and files where this information is not present will also fail.

In the case of DWAF Water Quality data files, many water quality components are stored in the same file and the time series import routine allows the user to select the type of data that should be imported (only a single variable may be associated with a single SPATSIM-HDSF Attribute). If more than one type of data is to be imported then the time series import routines must be run more than once, each time selecting the appropriate Attribute in which to store the data.

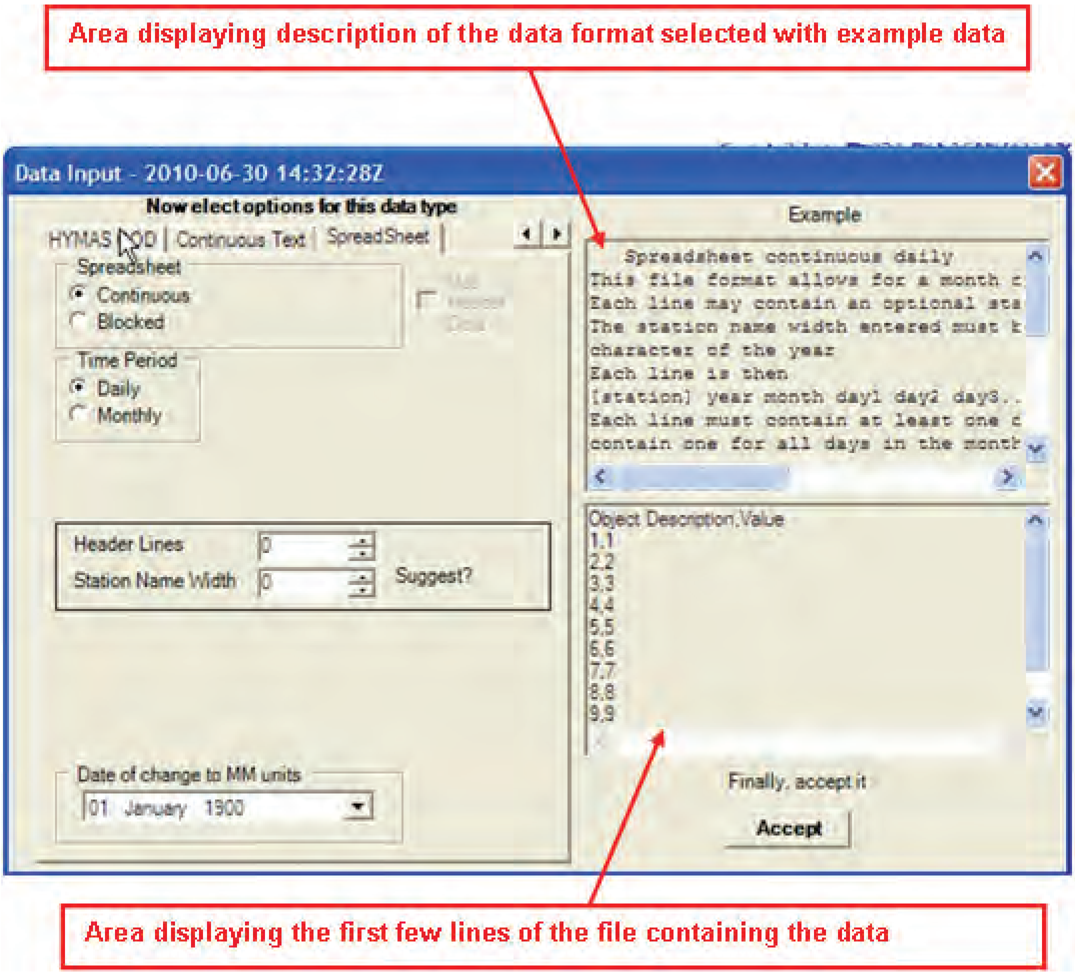


Figure 3.85 *Data Input* window enabling the selection of data type and additional options

The following describes an example of the selection process involved for the *Spreadsheet Continuous Daily* data file format within the *Data Input* window. This example is used to explain the process of using the description from the *Example* section of the *Data Input* window to decide on the options to choose for the file/s being imported.

The information contained within this paragraph on the file format of the *Spreadsheet Continuous Daily* is contained in the *Example* section of the *Data Input* window. The *Spreadsheet Continuous Daily* file format allows for a month of values per line. Each line may contain an optional station name at the start. If one line has it, all lines must have it. The station name width entered must be the index of the first character of the year. Each line is then:

[station] year month day1 day2 day3.....[day31] [avg]

Each line must contain at least one dayN value, but need not contain one for all days in the month. There must be no gaps i.e. zero values must be present. The optional average [avg] value is ignored. An example segment of a spreadsheet continuous daily is shown in Figure 3.86. In this example, there is one header line and the station name has 7 characters.

```
Optional header lines, specify the number
station 1967  1 0.24 0.23 0.52 0.62 0.22 0.25 3.47 1.59 0.64 0.82 0.20 0.47 0.04
station 1967  2 0.83 0.99 0.89 1.49 0.10 0.23 1.15
station 1967  3 0.09 0.31 0.29 2.07 1.05 0.80 0.17 0.29 0.05 0.28
station 1967  4 0.19 0.05 0.66 0.90 1.80
station 1967  5 0.18 0.13 0.04 0.09 0.03 0.02 0.49
```

Figure 3.86 Example file segment of Spreadsheet continuous daily

The following describes the specific options that need to be set to import *Spreadsheet Continuous Daily* file format. For other data file formats this process will differ and the information contained within the *Example* section of the *Data Input* window will assist in choosing the correct options. The *SpreadSheet* tab should be selected on the *Data Input* window as shown in Figure 3.87. The setup to import a S*preadsheet Continuous Daily* type file follows:

- The *Spreadsheet* option chosen is *Continuous*
- The *Time Period* option chosen is *Daily*.
- If a file contains a header the number of lines used for the header needs to be specified in the *Header Lines* numeric control.
- If each line of data contains a station name the width of the station name should be specified in the *Station Name Width* numeric control.
- The *Date of change to MM units* is used to cater for the scenario of a file containing time series rainfall data changing from inches to millimeters within the time series, particularly older rainfall files. Leave the date as *01 January 1900* if there is no unit change, but if there is a change, then the date the data changes units, should be set in the *Date of change to MM units* data time picker control. This ensures the data is converted were necessary to cater for consistent rainfall values.
- Clicking on the *Accept* button will import the time series data from the selected file or files.

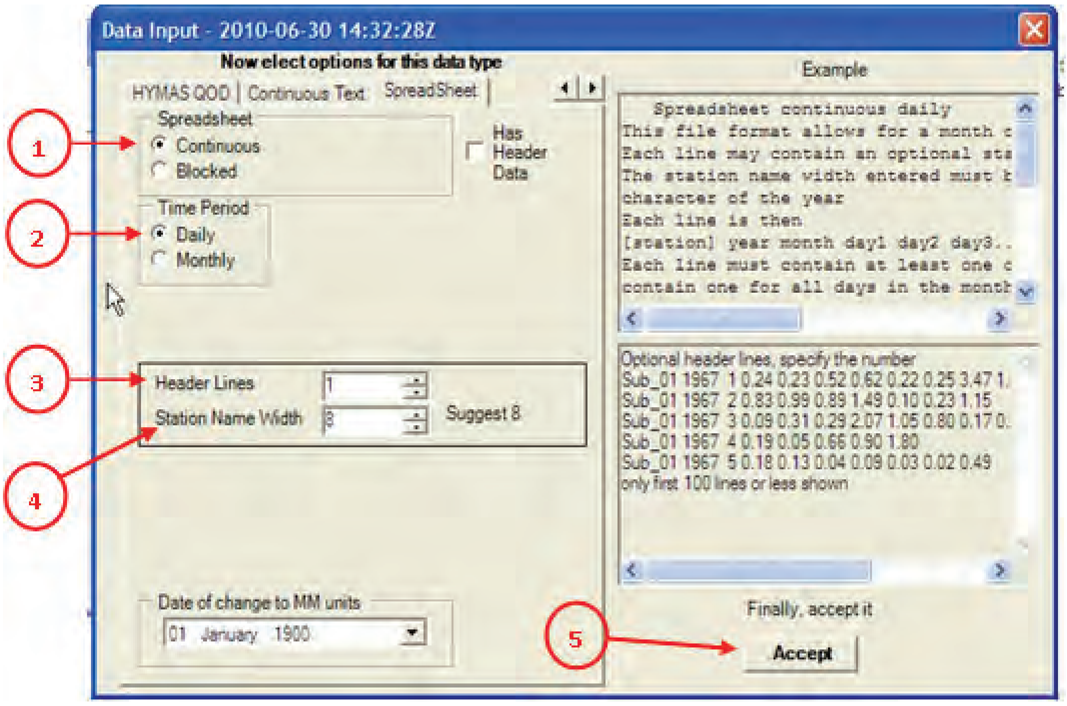


Figure 3.87 Example of an import of Spreadsheet Continuous Daily data input type

(iv) Specifying the time series metadata

Having selected the data type and additional options for importing of the selected files the *Generic Time Series Import* window shown in Figure 3.88 will be displayed. Before the data import can begin, it is necessary to check and modify any of the Attributes of the time series (such as data type, units and time intervals). Many of these are set by default according to the data type chosen, but in many cases the software is not able to reliably establish them. The *Data Obj* represents the type of time series imported. If the records in the time series are separated by a fixed interval of time the *Time Units* specify the time unit of the interval and the *Time Interval* specifies the length of the interval. For example, for a time series containing records at 2-day intervals, *Time Units* would be *Days* and the *Time Interval* would be *2*. The *Units* describes the unit of measurement of the values of the time series data. The *MD Code* sets the missing data code of the time series.

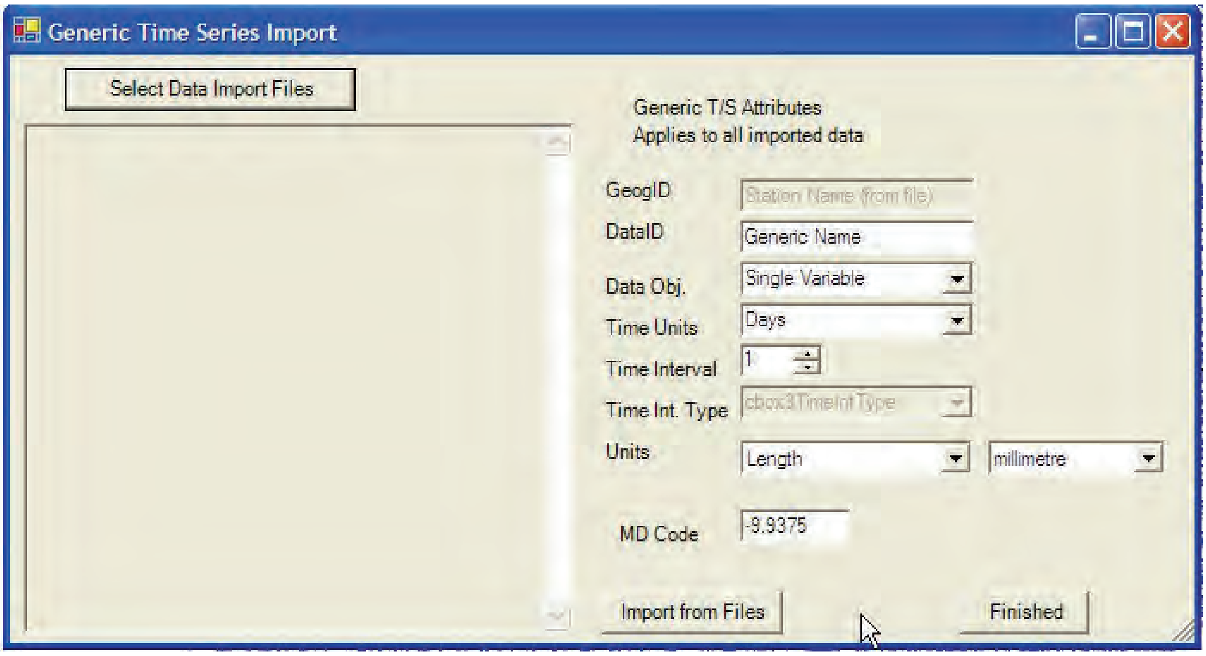


Figure 3.88 *Generic Time Series Import* window with files selected ready to be imported

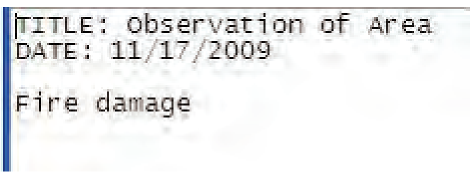
(v) <u>Completing the import</u>

The button *Import from Files* in the *Generic Time Series Import* window is used to initiate the data import and the left hand display box monitors and reports on the progress for the selected files.

The user may repeat the import process and specify the details for a further batch import from the *Generic Time Series Import* window by selecting *Select Data Import Files* button. However, it should be remembered that, the new data will also be imported to the already selected Feature and data Attribute.

Import text to Memo

The user may import text from a text file into a *MemoData* type Attribute. The text file should contain data in the format shown in Figure 3.89. It is essential that the relevant Feature and a *MemoData* type Attribute are selected before carrying out an import. The menu option to select for this facility is *Attributes -> Import Data -> Text to Memo* as shown in Figure 3.90. An *Open* file dialog window will be opened enabling the selection of a text file containing the data to be imported. Select the text file and click on the *Open* button to complete the process.



```
TITLE: Observation of Area
DATE: 11/17/2009

Fire damage
```

Figure 3.89 : Example of a text file containing memo import data.

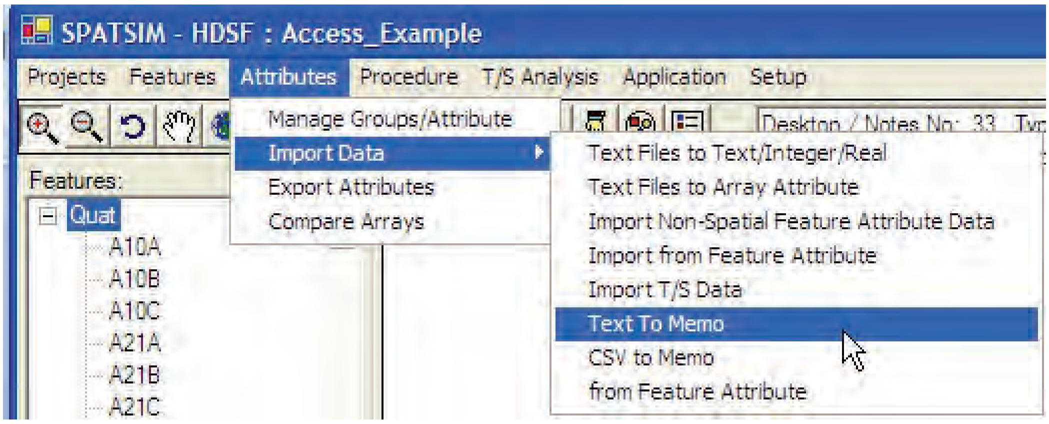
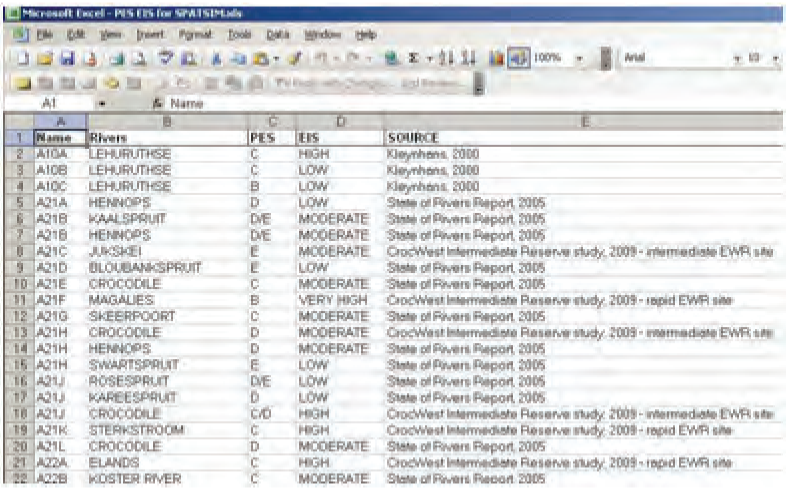


Figure 3.90 Import Text to Memo

Import CSV to Memo

This facility allows CSV files to be imported into a *MemoData* type Attribute. The information to be imported should be prepared in an excel spreadsheet with the first row containing the titles of the information to be imported. Figure 3.91 provides an example where there 5 items of information (Name, Rivers, PES, EIS and Source). The first column should always contain information that matches the DESC field in the Feature shapefile (i.e. the information that is displayed on the map for each spatial Object, such as polygons or points). The information in the first column is therefore used to identify which spatial Object to associate the information with. Once the information has been created in the excel spreadsheet it should be saved as a CSV file.



Name	Rivers	PES	EIS	SOURCE
A10A	LEHURUTHSE	C	HIGH	Kleynhans, 2000
A10B	LEHURUTHSE	C	LOW	Kleynhans, 2000
A10C	LEHURUTHSE	B	LOW	Kleynhans, 2000
A21A	HENNOPS	D	LOW	State of Rivers Report, 2005
A21B	KAALSPRUIT	D/E	MODERATE	State of Rivers Report, 2005
A21B	HENNOPS	D/E	MODERATE	State of Rivers Report, 2005
A21C	JUKSKEI	E	MODERATE	CrocWest Intermediate Reserve study, 2009 - intermediate EWR site
A21D	BLOUBANKSPRUIT	E	LOW	State of Rivers Report, 2005
A21E	CROCODILE	C	MODERATE	State of Rivers Report, 2005
A21F	MAGALIES	B	VERY HIGH	CrocWest Intermediate Reserve study, 2009 - rapid EWR site
A21G	SKEERPOORT	C	MODERATE	State of Rivers Report, 2005
A21H	CROCODILE	D	MODERATE	CrocWest Intermediate Reserve study, 2009 - intermediate EWR site
A21H	HENNOPS	D	MODERATE	State of Rivers Report, 2005
A21H	SWARTSPRUIT	E	LOW	State of Rivers Report, 2005
A21J	ROSESPRUIT	D/E	LOW	State of Rivers Report, 2005
A21J	KAREESPRUIT	D	LOW	State of Rivers Report, 2005
A21J	CROCODILE	C/D	HIGH	CrocWest Intermediate Reserve study, 2009 - intermediate EWR site
A21K	STERKSTROOM	C	HIGH	CrocWest Intermediate Reserve study, 2009 - rapid EWR site
A21L	CROCODILE	D	MODERATE	State of Rivers Report, 2005
A22A	ELANDS	C	HIGH	CrocWest Intermediate Reserve study, 2009 - rapid EWR site
A22B	KOSTER RIVER	C	MODERATE	State of Rivers Report, 2005

Figure 3.91 Example of CSV file containing memo data displayed in Microsoft Excel

It is essential that the relevant Feature and a *MemoData* type Attribute are selected before carrying out an import. The menu option to select for this facility is *Attributes -> Import Data -> Text to Memo* as shown in Figure 3.92. An *Open* file dialog window will be opened, enabling the selection of a CSV file containing the data to be imported. Select the CSV file and click on the *Open* button to complete the process. Figure 3.93 illustrates one of the memo entries that is created by the import.

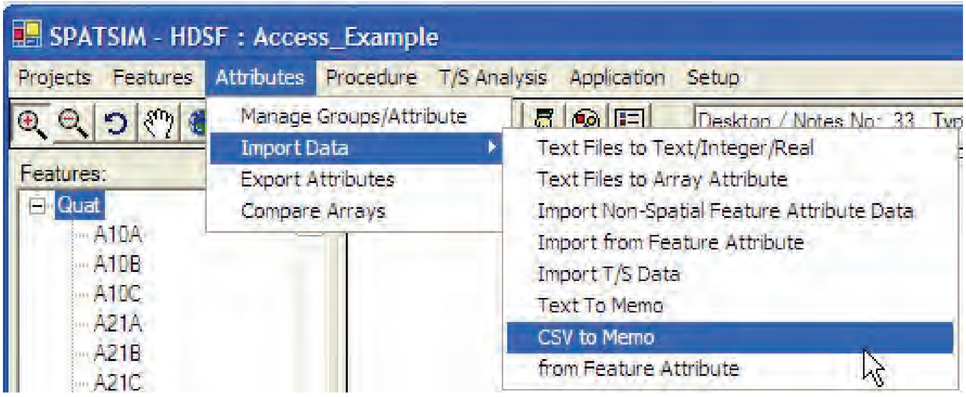


Figure 3.92 Selection of the *CSV to Memo* tool

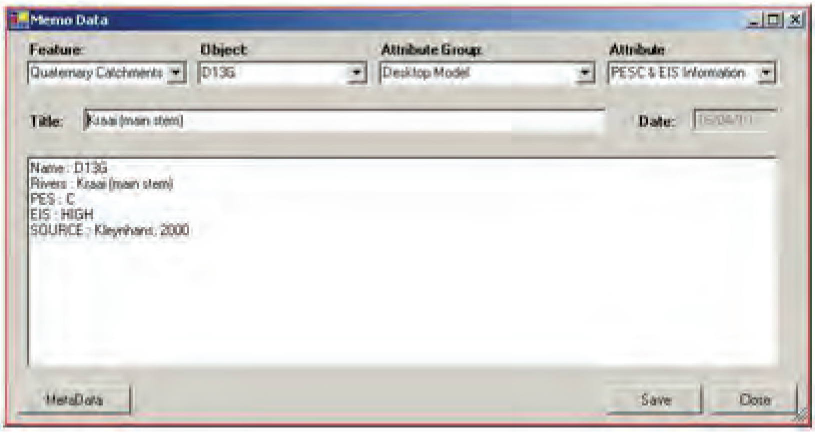


Figure 3.93 Example of a memo entry displayed in the Memo Data window

3.3.32 Export Data

Data stored in a SPATSIM-HDSF project database can be exported to a text file. The relevant Feature and Attribute should be selected first. The menu option to select for this facility is *Attributes -> Export Attributes* as shown in Figure 3.94. A *Save As* file dialog window will be displayed that enables the selection of a new or existing text file to which the data is to be exported. Once the file has been selected clicking on the *Save* button will result in the data being exported.

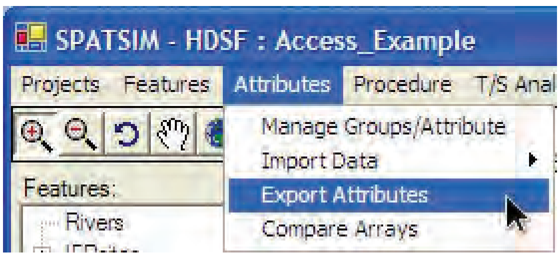


Figure 3.94 Selection of the *Export Attributes* tool

3.3.33 How to compare values in Array Attributes

The *Compare Arrays* window shown in Figure 3.95 has been developed to enable the comparison of rows or columns in an *ArrayData* type Attribute for two or more objects. One Object can also be selected to view a single Object's array values for a selected *ArrayData* type Attribute. The user may select one array column or one array row to be compared. While the *Compare Arrays* window is open the user may select a different *ArrayData* type Attribute using the selection controls at the top of the window. The *Compare Arrays* window also enables the editing of array values. Clicking on the *Save* button will save the edited data.

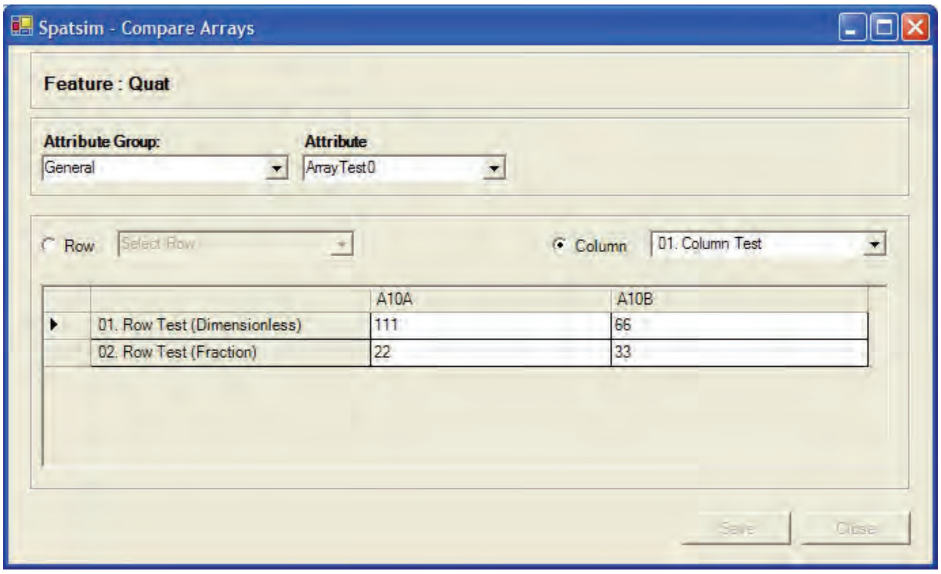


Figure 3.95 An example of the Compare Arrays window

The Object/s and an *ArrayData* type Attribute should be selected first. Refer to Section 3.3.30 for an explanation of how to select multiple objects. Next select *Attributes -> Compare Arrays from the menu* as shown in Figure 3.96. The *Compare Arrays* window will be displayed as shown in Figure 3.95 and populated with the Attribute data for the selected objects. If either of the objects do not contain data then no data will be displayed for that Object.

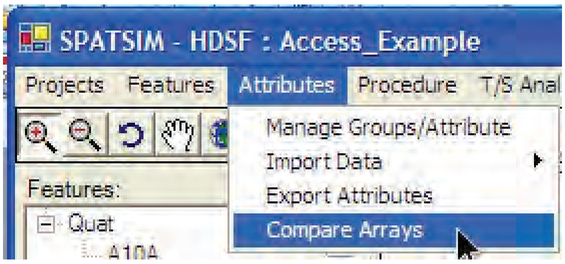


Figure 3.96 Selecting the *Compare Arrays* option

3.3.34 How to view and filter data in the Data tab

The *Data* tab displays Attribute value data for a selected Feature and Attribute Group window. The left-most column on the *Data* tab, named *Object*, displays a list of Object names. To the right of the *Object* column a set of columns is displayed, one for each Attribute in the selected Attribute Group. For the simple Attribute types *TextData*, *IntegerData* and *RealData* the data values will be displayed in the cells of the data grid. For the more complex Attribute types *TimeSeriesData*, *PictureData*, *ArrayData*, *MemoData* and *LinkData* the Attribute data type is displayed in the cells of the data grid. This section discusses how to view and filter data in the *Data* tab.

Above the data grid on the *Data* tab is a set of record selection controls as shown in Figure 3.97. The *Select* controls enable the user to filter and display a subset of the objects in the data grid by selecting a column in the data grid and specifying a condition and a constraint. For example, applying the condition "Starts With" and the constraint "V" to the *Object* column for a Feature containing quaternary catchments would display all the quaternary catchment objects with a description starting with the letters "V". The default condition is *All*, which will cause all the objects in the Feature to be displayed in the data grid.

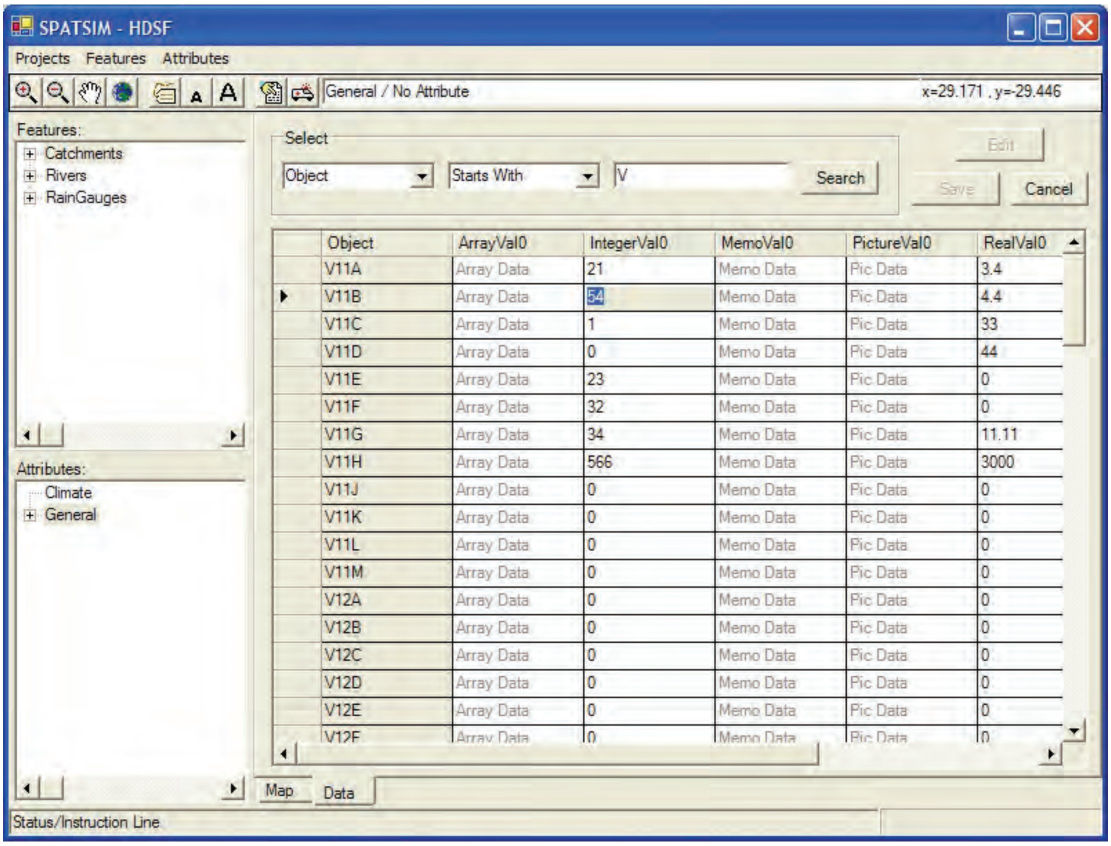


Figure 3.97 An example of the Data tabbed page

3.3.35 How to edit data in the Data tab

In the *Data* tab the data grid is by default disabled for editing. If the user needs to edit an Attribute value then the *Edit* button should be clicked to make the data grid editable. When the data grid is editable the user may edit Attribute values for *TextData*, *IntegerData* and *RealData* type Attributes directly in the cells of the data grid. Alternatively all Attribute data types may be edited by right-clicking with the mouse on a cell in the data grid and selecting the *Edit* command from the popup menu to open the appropriate Attribute data value editing window. These Attribute editing forms are explained in further detail in Section 3.3.36. Once the user has edited one or more *TextData*, *IntegerData* or *RealData* type Attribute values in the data grid, the *Save* button may be used to save edits or the *Cancel* button to reject unsaved edits and repopulate the data grid with the original Attribute values from the database. The user is prompted to save any unsaved edits before selecting a different Attribute Group.

3.3.36 How to view and edit data in the data editing windows

The Attribute data editing tools consists of a set of windows, one window for each of the Attribute data types, namely: *TextData*, *IntegerData*, *RealData*, *TimeSeriesData*, *PictureData*, *ArrayData*, *MemoData* and *LinkData*. The Feature Attribute data editing windows enable the user to view and edit Attribute data for a selected Feature, Object and Attribute. To access these data editing windows the user must first select a Feature, an Object within this Feature and an Attribute on the main SPATSIM-HDSF window and then click on *Show Attribute Data* button as shown in Figure 3.98.

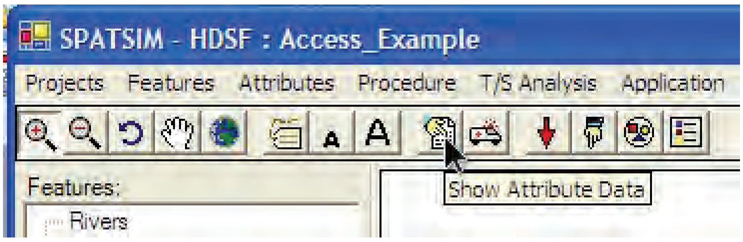


Figure 3.98 The *Show Attribute Data* toolbar button

Feature Attribute data

An example of the *Text Data* Attribute data editing window is shown in Figure 3.99. Before displaying this window the user must first select a Feature, Object and *TextData* type Attribute on the main SPATSIM-HDSF window. Once the *Text Data* window is open the user may use the *Feature*, *Object*, *Attribute Group* and *Attribute* controls to select other *TextData* type Attributes in other Features or Attribute Groups to be edited. The user may edit and then save the text data associated with the selected Attribute. The user may also view and edit the metadata associated with the selected Attribute value by clicking on the *Metadata* button.

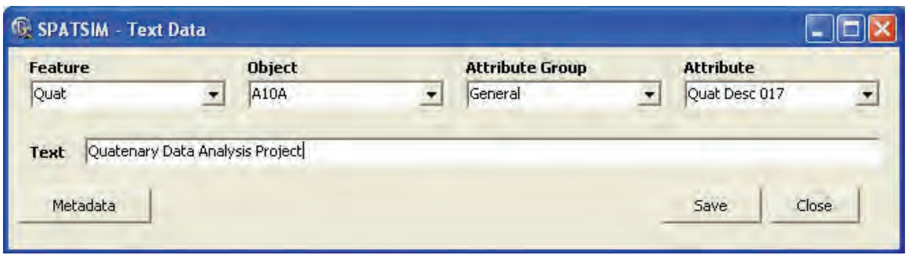


Figure 3.99 An example of the *Text Data* Attribute data editing window

An example of the *Integer Data* Attribute data editing window is shown in Figure 3.100. This window works in a similar manner to the *Text Data* window. In addition, units of measure associated with the Attribute value are displayed on the *Integer Data* window. However, the user may not change the units of measure for the

Attribute value shown on this window as the units of measure are set by the user for the Attribute as a whole on a different window.

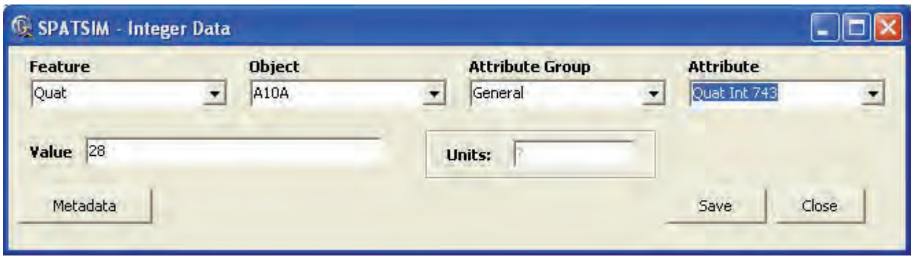


Figure 3.100 An example of the *Integer Data* Attribute data editing window

An example of the *Real Data* Attribute data editing window is shown in Figure 3.101. This window works in a similar manner to the *Integer Data* window.

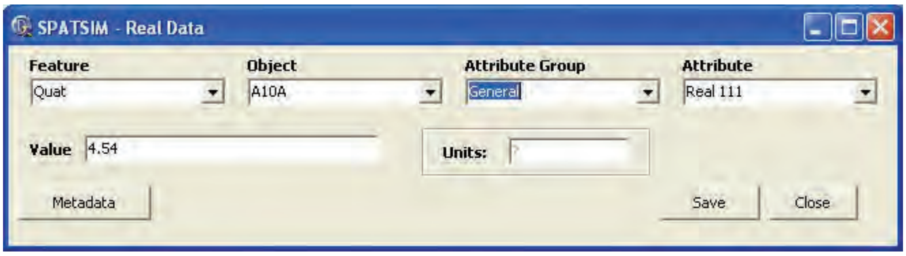


Figure 3.101 An example of the *Real Data* Attribute data editing window

An example of the *Time Series Data* Attribute data editing window is shown in Figure 3.102. The Feature, Object and Attribute selection works in a similar manner to the previously mentioned Attribute data editing windows. On the left-hand side of this window there is a table displaying the date, time, value and flag information stored in the database for the selected *TimeSeriesData* type Attribute. In this table the user may edit the time series subject to a set of appropriate rules based on the type of time series.

On the right-hand side of this window there are a set of controls that the user may use to edit information related to the selected *TimeSeriesData* type Attribute, such as *Geog ID*, *Data ID*, *Aggregation Type*, *Units, Scale*, *TS Type*, *Time Units*, *Time Interval*, *Flags*, *MD Code*, *Start Date, Start Time*, *End Date* and *End Time*. The *Geog ID* control enables the user to enter text describing the source of the time series data. The *Data ID* enables the user to enter text describing the time series data type. *Aggregation Type* is the recommended type of aggregation if the time series data needs to be aggregated. The *Units* control specifies the units of measure of the time series data. The *Scale* control is used to specify a value by which to scale the data values, for example when plotting the time series on a graph, *Scale* = 2 will result in all the time series values being plotted at two times their original value. *TS Type* describes the type of time series such as *Fixed Interval, Variable-Interval* and *Variable-Date Time*. For a *Fixed Interval* time series each record consists only of a data value, the time interval between the time series are of equal size, therefore in the case of a *Fixed Interval* time series *Time Units* defines the unit of time of the fixed interval and *Time Interval* is the length of the fixed interval. For a *Variable-Interval* time series type each record consists of an interval length and a data value, intervals are variable between the time series values, thus the *Time Units* defines the unit of time of the variable intervals, but there is no need to set the *Time Interval* as the lengths are not fixed between the time series values. In the case of *Variable-Date Time* each record consists of a date/time value and a data value, there is no need to define the *Time Units* or the *Time Interval*. *Flags* are used to set the data quality flag set used to flag data within a time series, an example could be flags to indicate certain levels of inaccuracies with a measurement. Clicking on the *View Flag Key* button displays the flag set chosen and allows editing of the flag set. *MD Code* is generally a value in the time series that signals a missing data value within the time series, such as -9.999, which assists when analyzing data. *Start Date* and *Start Time* represent the start of the time series data set, and *End Date* and *End Time* represent the end of the time series data set. Clicking the *Write to File* option will output the time series data to a comma separated file. Clicking the *Export T/S* option will output the time series data in a format that can be later imported back into the SPATSIM-HDSF database. This import process of time series data is detailed in Section 3.3.31.

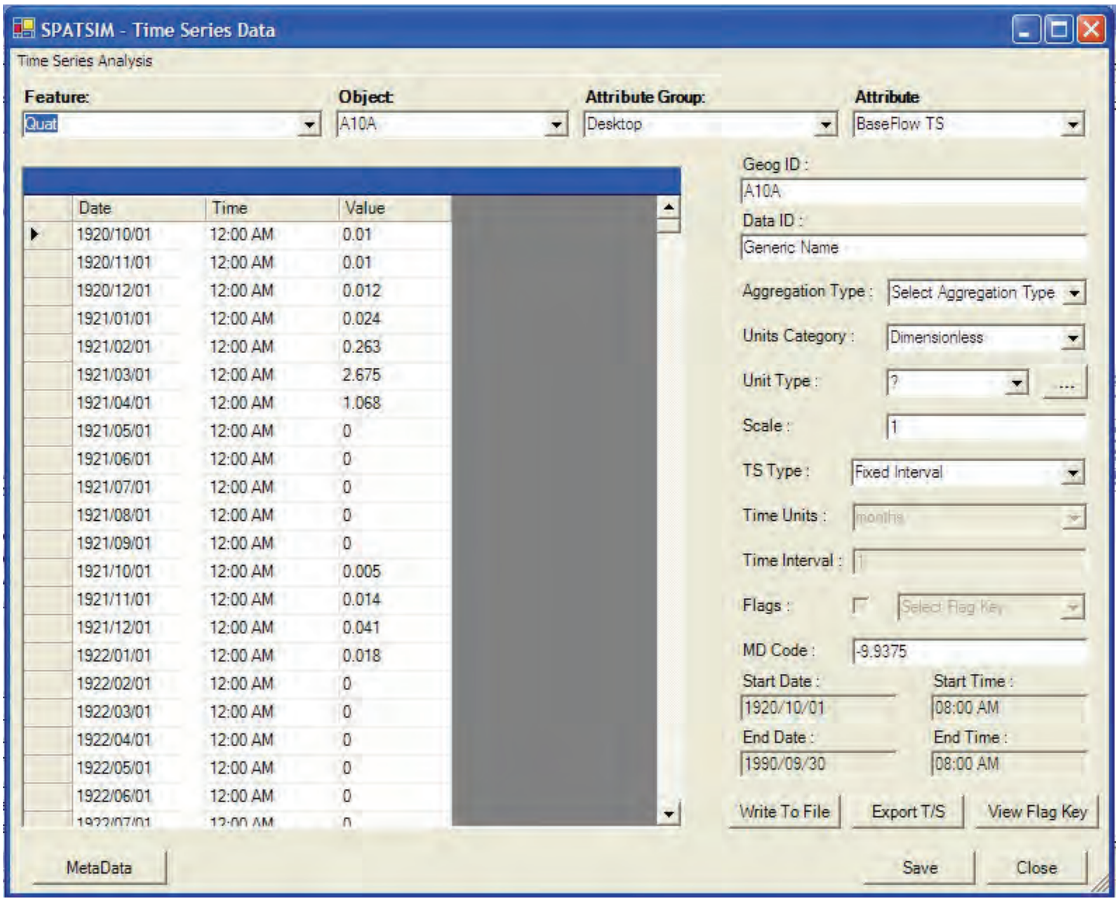


Figure 3.102 An example of the *Time Series* Data Attribute data editing window

An option in the *Time Series Data* Attribute data editing window is to carry out certain analysis and operations on the time series dataset currently being viewed. These analyses and operations form part of the *TSAnalysis Tools* discussed in Section 2.1.4. The analyses and operations are accessed by clicking on *Time Series Analysis* from the main menu of the *Time Series Data* Attribute data editing window as shown in Figure 3.103.

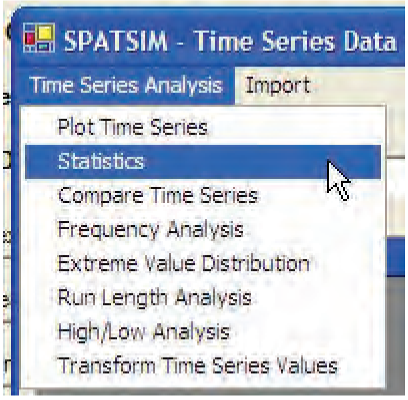


Figure 3.103 Accessing the *Time Series Analysis* options from the *Time Series Data* attribute data editing window

An example of the *Picture Data* Attribute data editing window is shown in Figure 3.104. This window displays the picture stored for the selected Feature, Object and Attribute. The title, storage date, size and type of the picture is also displayed on the window. The user may load a new picture by clicking on the *Load Graphic* button and then selecting the relevant file using the file selection dialog window. The user may also export the picture by clicking on the *Export Graphic* button and then specifying a name for the file using the file save dialog window.

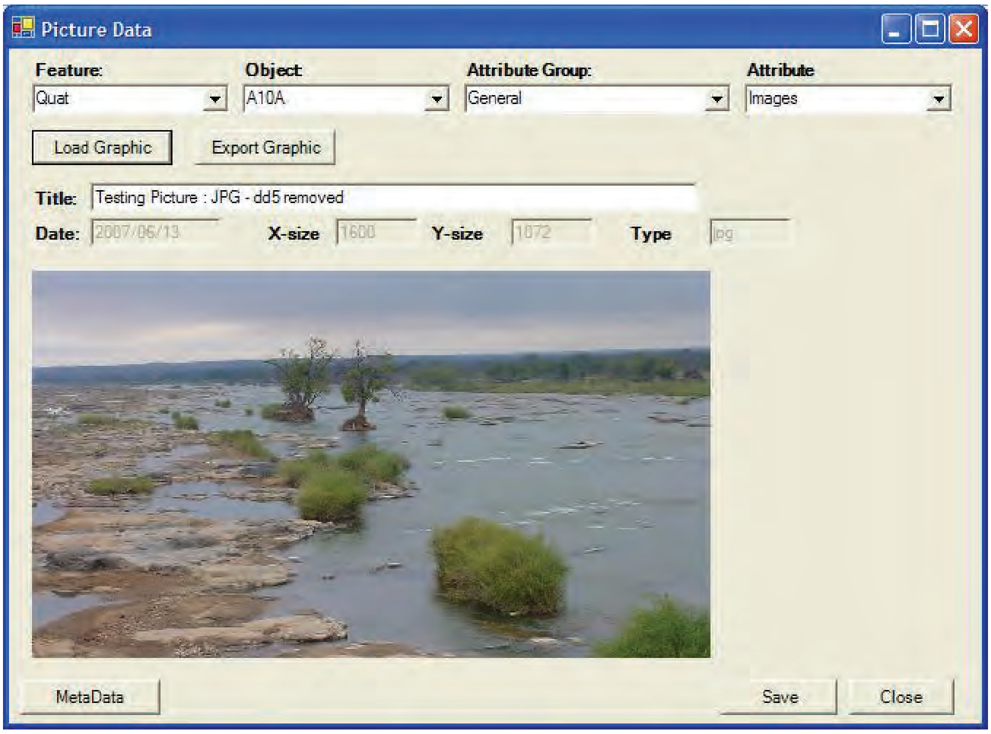


Figure 3.104 An example of the *Picture Data* Attribute data editing window

An example of the *Array Data* Attribute data editing window is shown in Figure 3.105. This window displays an array of numbers stored for the selected Feature, Object and Attribute. The title and information about the format of the array is also displayed in the window. The user may edit and then save individual data values in the array. Tools are provided to enable the user to import data into the array or to export or print array data. Additional tools are provided to enable users to copy or scale existing array data.

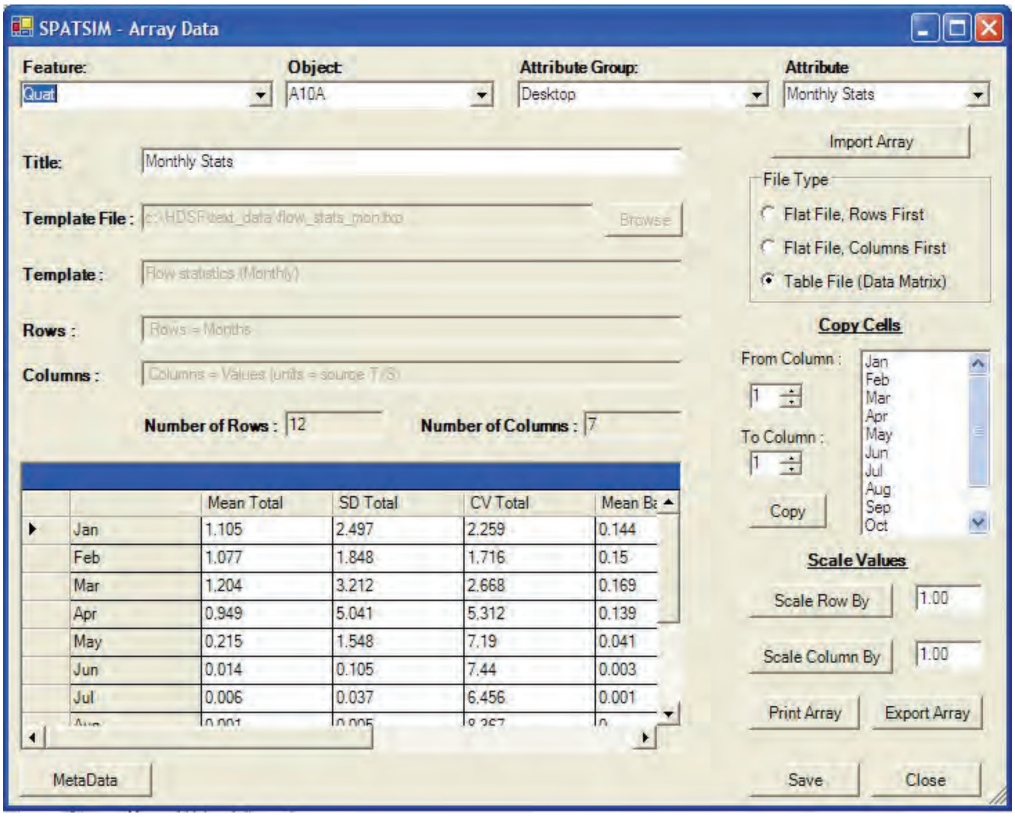


Figure 3.105 An example of the *Array Data* Attribute data editing window

An example of the *Memo Data* Attribute data editing window is shown in Figure 3.106. This window displays memo text stored for the selected Feature, Object and Attribute. The title and memo creation date are also displayed in the window.

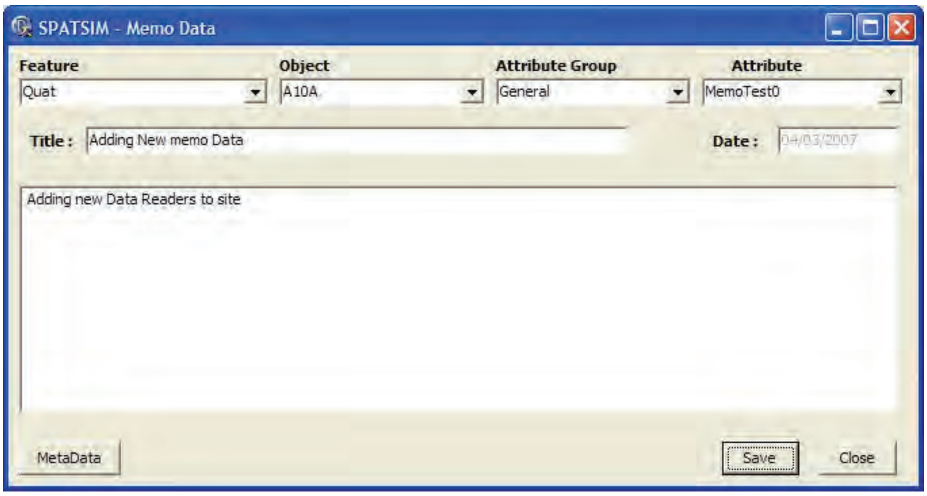


Figure 3.106 An example of the *Memo Data* Attribute data editing window

An example of the *Link Data* Attribute data editing window is shown in Figure 3.107. This form displays information about a linked Attribute for the selected Attribute and

Object. The purpose of linked Attributes is to prevent replication of data and enables data stored in the database for one Attribute and Object to be used by one or more other Attributes and Objects. For the selected Attribute and Object the user may specify the source Attribute and Object containing the data to be referenced by the link. Both the selected Attribute and the source Attribute must be of the same data type.

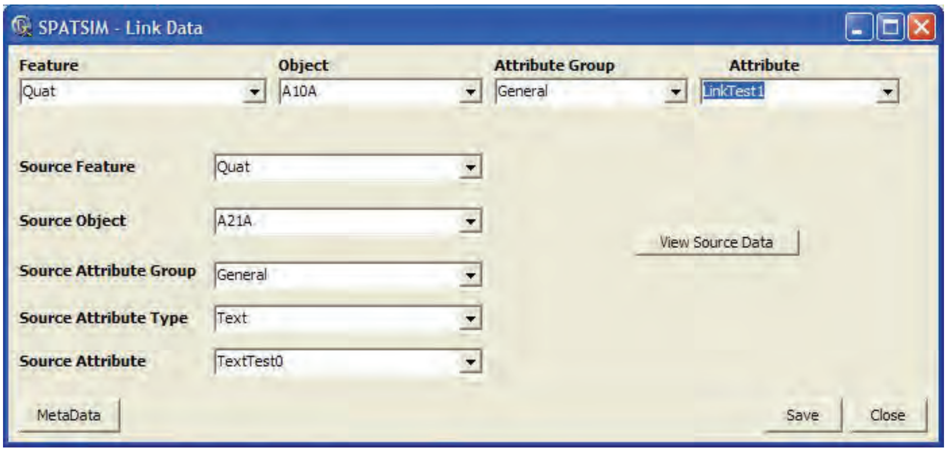


Figure 3.107 An example of the *Link Data* Attribute data editing window

In most of the data editing windows there is a *MetaData* button. Clicking on this button will display the *Attribute Value Metadata* window shown in Figure 3.108. This window enables metadata to be entered and edited against an Attribute value using the *Attribute Value Metadata* window as shown in Figure 3.108.

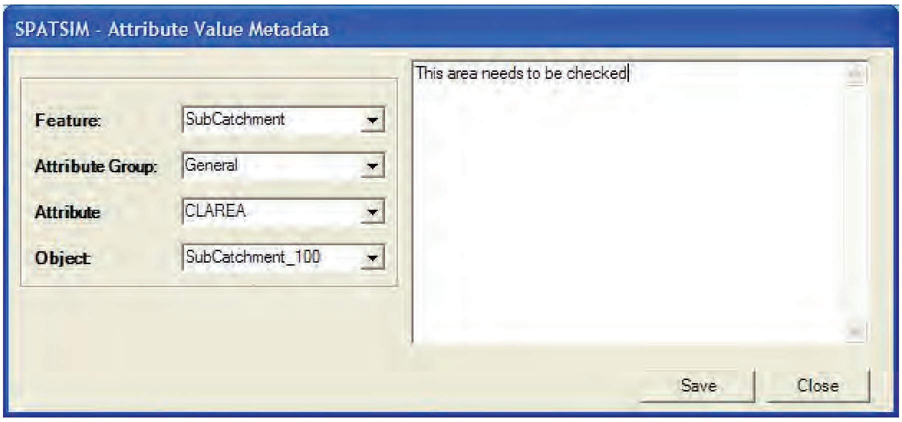


Figure 3.108 Example of the *Attribute Value Metadata* window

Process Attribute data

The SPATSIM-HDSF data model facilitates the storage of additional information about individual process runs, by means of a set of process Attribute Groups and Attributes. Therefore a set of process Attribute data editing windows has also been created to enable process Attribute data to be edited. The process Attribute data editing windows are very similar to the Feature Attribute data editing windows and therefore, have not been described in this report.

3.3.37 How to use the T/S Summary Procedure

The *T/S Summary* procedure was mainly designed to generate summary information for a time series of flow data (monthly or daily time steps), but can also be used for rainfall data if required. The time series summary procedure, illustrated in Figure 3.109, is started by first selecting an Attribute within SPATSIM-HDSF that contains a time series of flow data. This will be the default time series that is analysed and summarised. The next step is to select *Procedure->T/S Summary* from the SPATSIM-HDSF menu.

The next step if necessary is to select the time series data to be analysed if the default data are not to be used. Simply highlight a time series Attribute in the *Input Attribute List* box and then double click on the right hand column of the 'Flow Data (monthly or daily)' row in the *Input Attributes* grid.

It is also necessary to specify the baseflow separation parameters to be used for some of the statistics. Find and highlight a suitable array type Attribute (that contains the alpha and beta parameters for both daily and monthly time step data) in the *Input Attribute List* and then double click on the appropriate right hand column of the *Input Attributes* grid. If an Attribute is not selected default baseflow parameters will be used.

There are four possible sets of output data:

- Duration or frequency curves for individual calendar months and for the total year (an array Attribute with 17 rows and 12 columns).
- Monthly statistics of the time series including means, standard deviations for total and baseflow (an array Attribute with 12 rows and 6 columns). The data stored (for each month) are:
  - Mean Total
  - SD Total
  - CV Total
  - Mean Baseflow
  - SD Baseflow
  - CV Baseflow
- Annual statistics including some of the index values used in the Desktop Reserve model (an array Attribute with 14 rows and 1 column). The baseflow separation parameters are also written for reference purposes. The data stored are:
  - Mean Total
  - SD Total
  - CV Total
  - Daily Alpha
  - Daily Beta
  - Monthly Alpha
  - Monthly Beta
  - Mean Baseflow
  - SD Baseflow
  - CV Baseflow
  - Freq.of Zero Flow
  - CV Index
  - BFI
  - Hydrol.Var.Index

- Baseflow Time Series data (a time series Attribute).

The units used in all the outputs are the same as the units used in the input time series data. For example, if the input time series data are monthly flows in million cubic metres, the flow duration curve values and all the statistics will be in the same units (except the non-dimensional indices). It is important therefore to name the output Attributes accordingly.

Clicking on the *Process Time Series Data* button will generate output statistics for all the spatial elements in the selected Feature for which there are input data. This is therefore a very quick way of getting a summary of time series data for a large number of points or polygons associated with a spatial Feature.

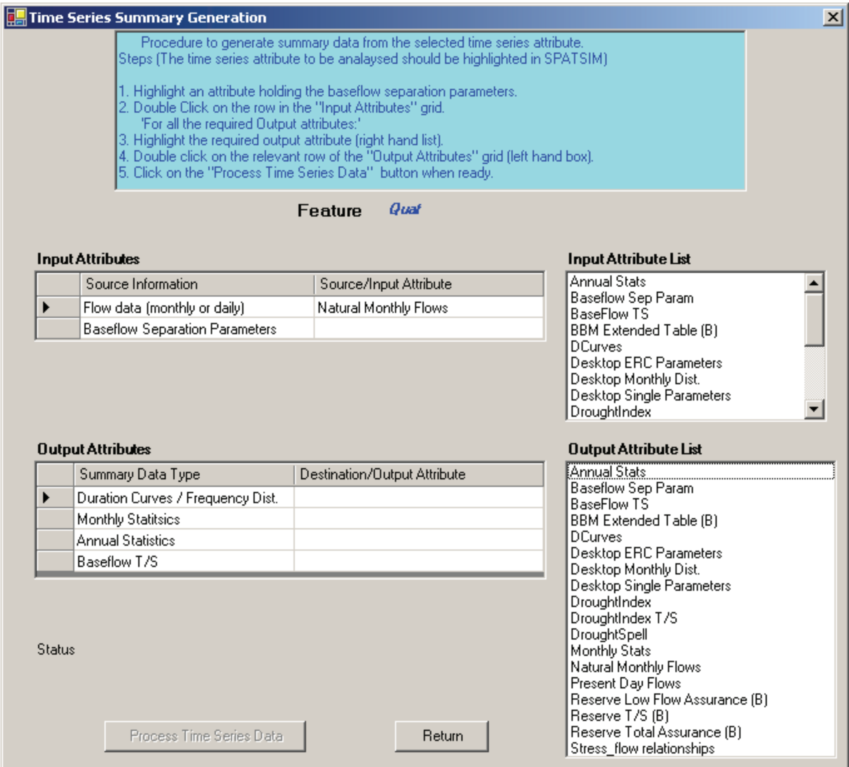


Figure 3.109 Time series summary main page.

3.3.38 How to use the Drought Indices Procedure

There are two components to this procedure. The first is to generate time series of drought indices from input monthly rainfall data, while the second is to extract some of the indices from specific years and use these to render a map and investigate regional patterns of drought severity.

The drought index generation process, illustrated in Figure 3.110, is more fully described in the online SPATSIM-HDSF help documentation available on the IWR webpage [http://www.ru.ac.za/static/institutes/iwr/software/reserve/helpdss/main_frame.htm]).

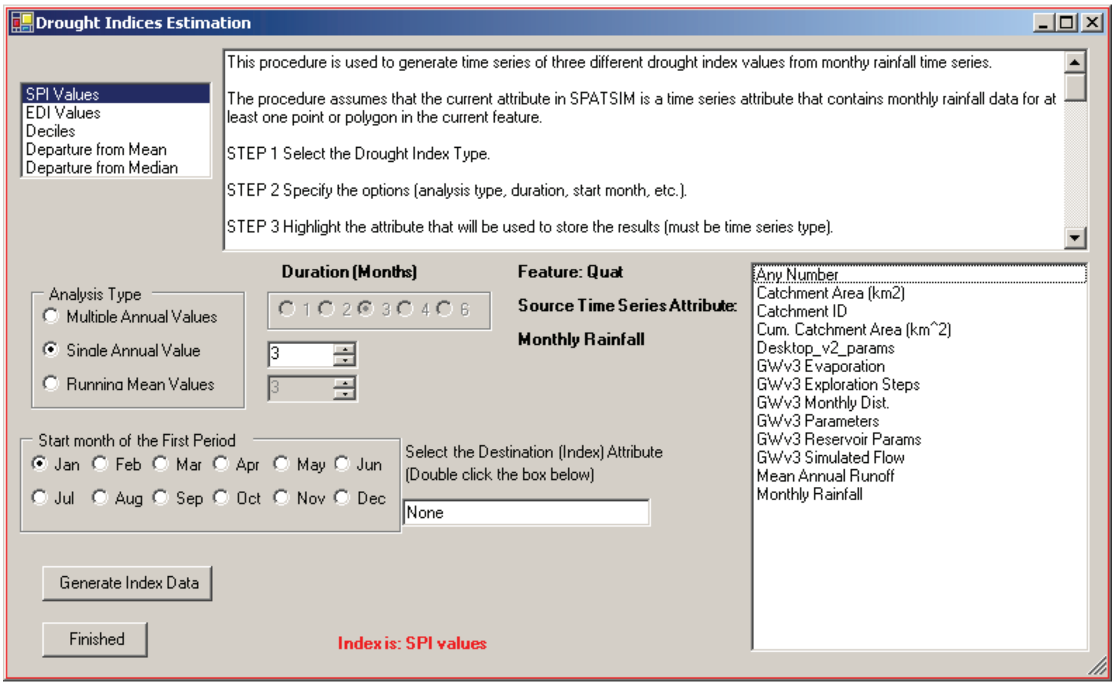


Figure 3.110 Drought indices generation main page.

3.3.39 How to use the *Sub Quat MAR* Procedure

One of the problems frequently experienced in Desktop or Rapid Reserve determinations is the need to scale quaternary level streamflow data to a point on the river that is within the quaternary catchment. Simple catchment area based scaling frequently does not work very well due to the spatial variations in rainfall and runoff response. The procedure *Sub-Quat. M*AR has been established to facilitate the use of this approach, which is more fully described in the online SPATSIM-HDSF help [http://www.ru.ac.za/static/institutes/iwr/software/reserve/helpdss/sp_frame.htm].

3.3.40 How to use the TSAnalysis tools

The Time Series Analysis (TSAnalysis) utility has been developed to aid users in the analysis of time series data. Select *T/S Analysis* from the SPATSIM-HDSF menu to access the different TSAnalysis tools as shown in Figure 3.111. Detailed instructions on how to use the TSAnalysis tools can be found in the TSAnalysis User Manual (Lutchminarain, 2010).

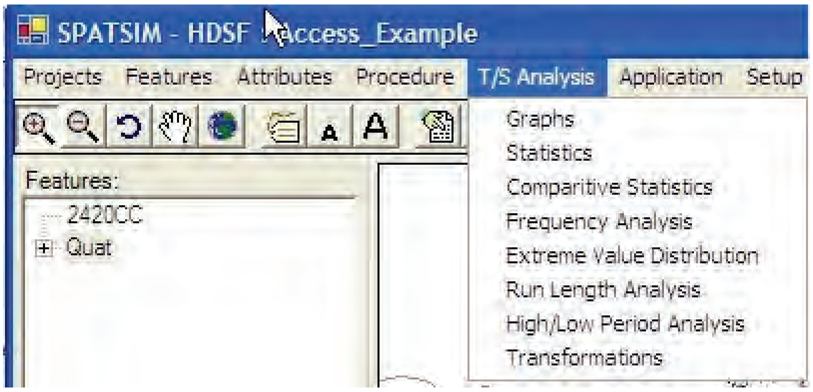


Figure 3.111 Accessing T/S Analysis tools from SPATSIM-HDSF

3.3.41 How to use the T/S Graphs tool

The TSGraph application for analysis of time series can be started directly from SPATSIM-HDSF, in which case the user is expected to select an existing Profile file before starting an analysis. If a suitable Profile file with references to time series data stored in SPATSIM-HDSF does not exist, then a new Profile file will need to be created. The following describes this process:

(i) Select *Application->T/S Graphs->Add to Profile* from the SPATSIM-HDSF menu as shown in Figure 3.112.

(ii) The *Select one or more spatial elements* button in the toolbar is activated and a multiple selection listbox appears over the M*ap* tabbed page. Select one or more objects as explained in Section 3.3.30.

(iii) Once the objects have been selected deactivate the *Select one or more spatial elements* button by clicking on it. This will result in a confirmation window being displayed as shown in Figure 3.113. Select the *Yes* button.

(iv) A window will then be displayed to capture the new Profile name as shown in Figure 3.114. Enter the new Profile name. Note the Profile name entered should be a unique Profile name relative to the SPATSIM-HDSF project. Click on the *OK* button.

(v) A window will be displayed listing the objects added and objects not added to the new profile. Objects will not be added to the Profile if no data exists for those Objects in the selected Attribute. A new Profile has now been created.

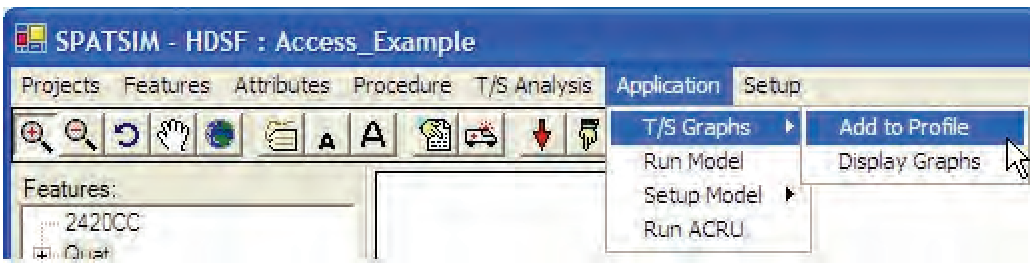


Figure 3.112 Selecting Add to Profile to create a new or add to an existing profile file

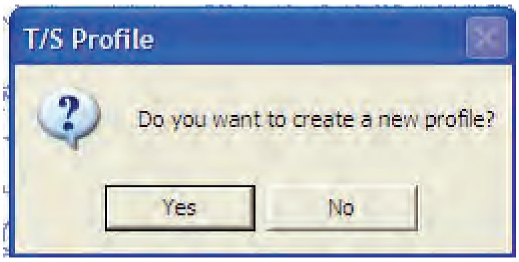


Figure 3.113 Window requesting confirmation to create a new Profile file

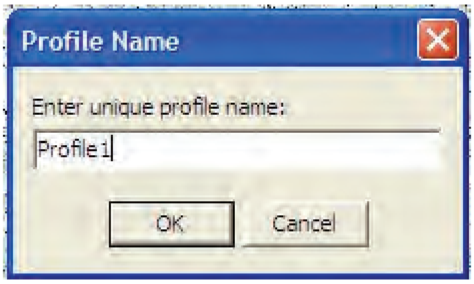


Figure 3.114 Window to capture the new Profile name

In the case of adding data references to an existing Profile file. Repeat steps (i) and (ii), and in step (iii) instead of clicking on the *Yes* button, click on the *No* button. This will bring up a list of existing profile files as shown in Figure 3.115. Double click the required Profile file from the list to add the Objects selected to the existing Profile file.

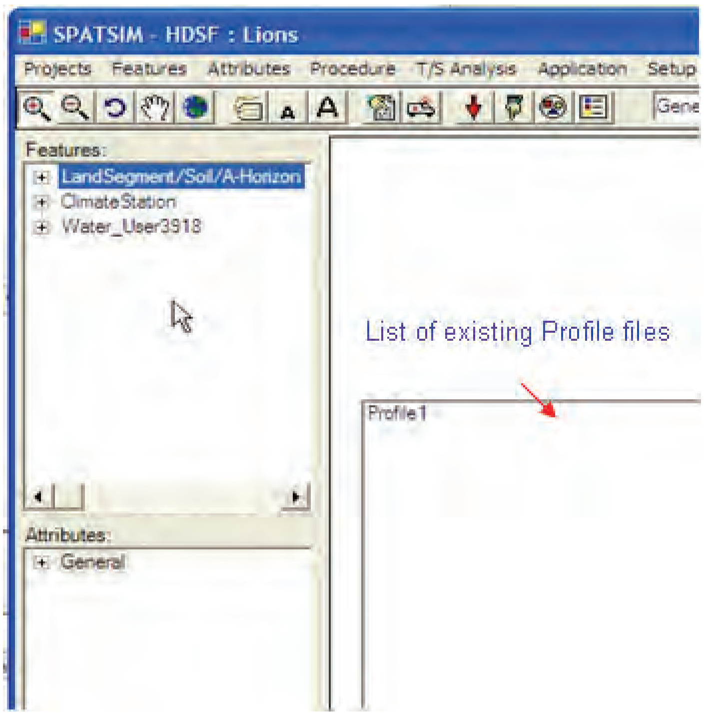


Figure 3.115 Example of list of existing Profile files

Once a Profile file has been created we can use the TSGraph tool. From the SPATSIM-HDSF menu select *Application->T/S Graphs->Display Graphs* as shown in Figure 3.116. A window appears with a list of Profiles associated with the current SPATSIM-HDSF project loaded as shown in Figure 3.117. Select a Profile and click on the *Accept* button and the main TSGraph window with graph areas will be displayed as shown in Figure 3.118.

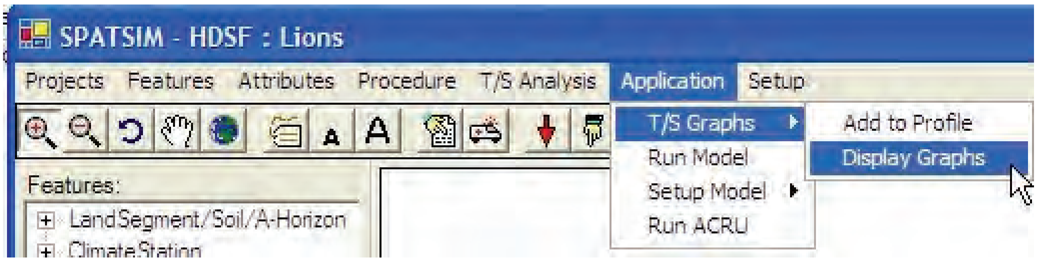


Figure 3.116 Running TSGraphs from SPATSIM-HDSF

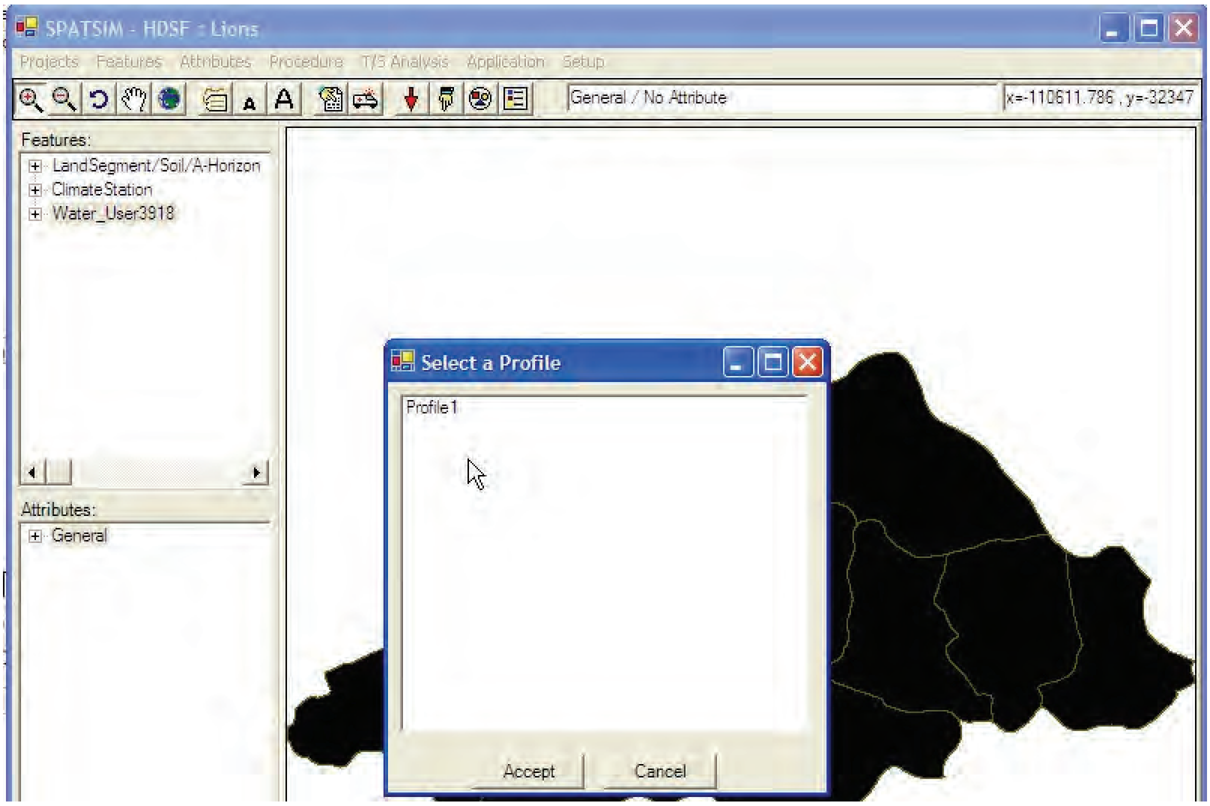


Figure 3.117 Select a Profile for TSGraph

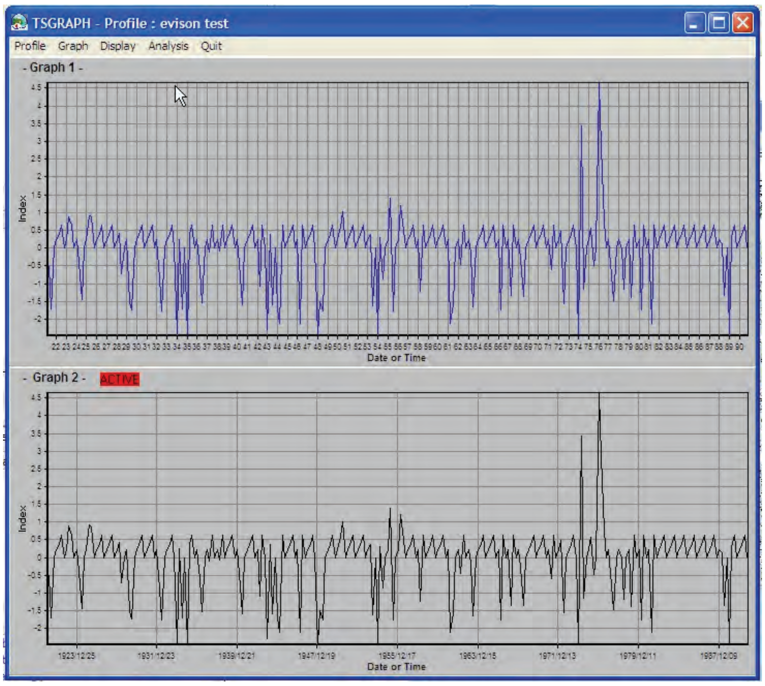


Figure 3.118 TSGraph main interface with data plotted

TSGraph enables either one or two graphs to be displayed and each graph may include one or more time series as shown in Figure 3.118. If a time series on a graph is selected using the mouse, then the name of the time series and the mean and standard deviation of the time series is displayed. The user may zoom-in to or zoom-out from a section of the active graph by dragging a box using the left-hand mouse button. The user may scroll the active graph using the right-hand mouse button. The *Graph* menu contains the following menu items related to the plotting and management of graphs in TSGraph:

- *Add* – The user may select a time series from the active profile to be plotted on the active graph. The time series may be plotted as a single time series for a specified time period or as a set of time series for selected months-of-year and years. Before the graph is plotted the user may select a time series conversion operation including:
    - integration of the time series for a selected time step using a mean, running mean or sum,
    - standardisation by catchment area or mean values, and
    - scaling to different units of measure.
- *Remove* – The user may remove a time series from the active graph.
- *Key* – Shows a window containing a key to the time series displayed in the active graph.
- *Print* - The user may choose to print Graph 1, Graph 2 or both graphs.
- *To text file* – The user may save the data values for the time series in the active graph to a text file.
- *To Graph File* – The user may save an image of the active graph in Windows Metafile (.wmf) format.

The *Display* menu contains the following menu items:

- *Scale* – This menu item contains further menu items enabling the user to format the y-axes and display the y-axes of the active graph on a linear or a log scale.

- *Show* - The user may choose to display Graph 1, Graph 2 or both graphs.
- *Colours* – The user may change the background colour of the active graph and where necessary the colours used to display the time series are changed.

The *Analysis* menu contains the following menu items:

- *Monthly Dist* – The user may select one or more time series from the active graph, the month-by-month means for each time series are then calculated and plotted on a graph as shown in Figure 3.119. The graph may be printed or saved as an image in Windows Metafile (.*wmf*) format.

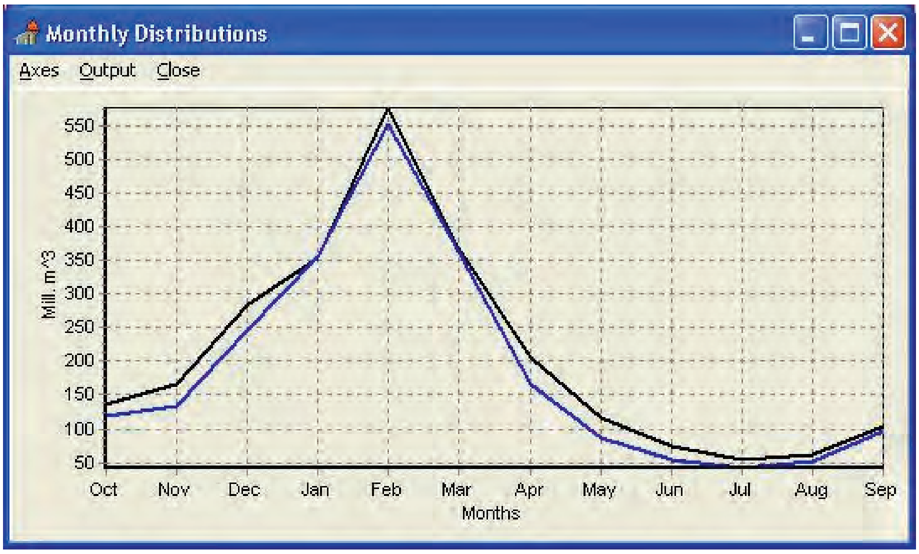


Figure 3.119 Example of the *Monthly Distributions* window in TSGraph

- *D.Curve* – There are two options: standard and month-by-month. For the standard option the user may select one or more time series from the active graph and one or more months of the year, a frequency distribution analysis is performed for each time series for the values in the selected months and plotted on a graph as shown in Figure 3.120. For the month-by-month option the user may select a time series from the active graph and one or more months of the year, a frequency distribution analysis is performed for each month in the selected time series and plotted on a graph as shown in Figure 3.121. The frequency distribution graph may be printed or saved as an image in Windows Metafile (.*wmf*) format and the data points on the graph may be saved to a text file.

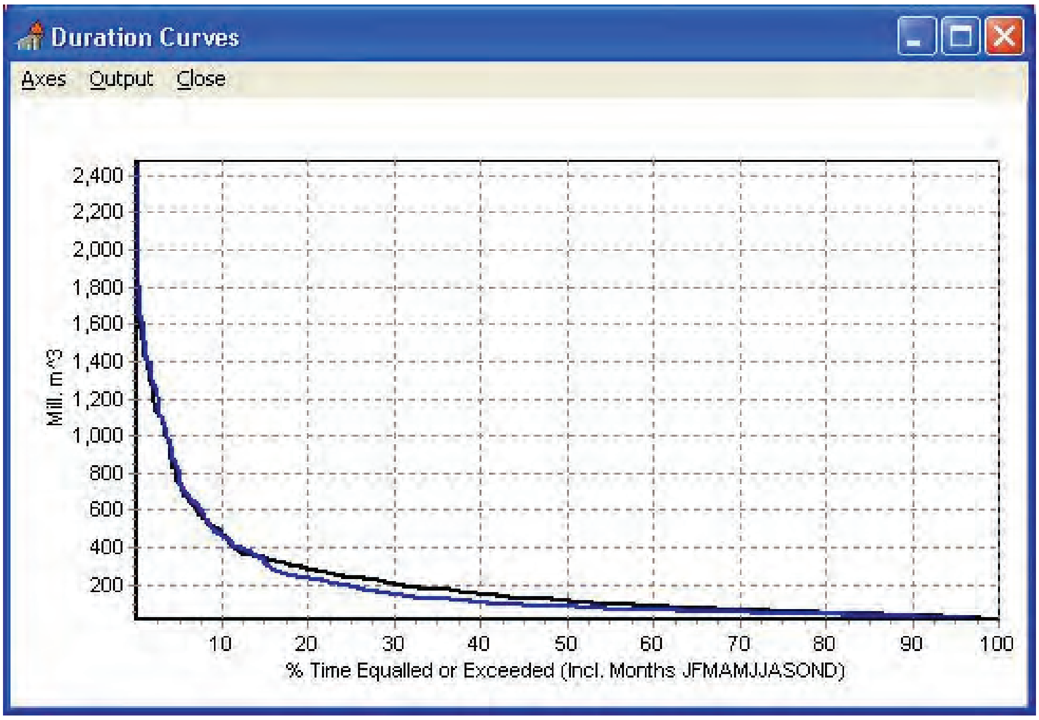


Figure 3.120 Examples of the *Duration Curves* window in TSGraph

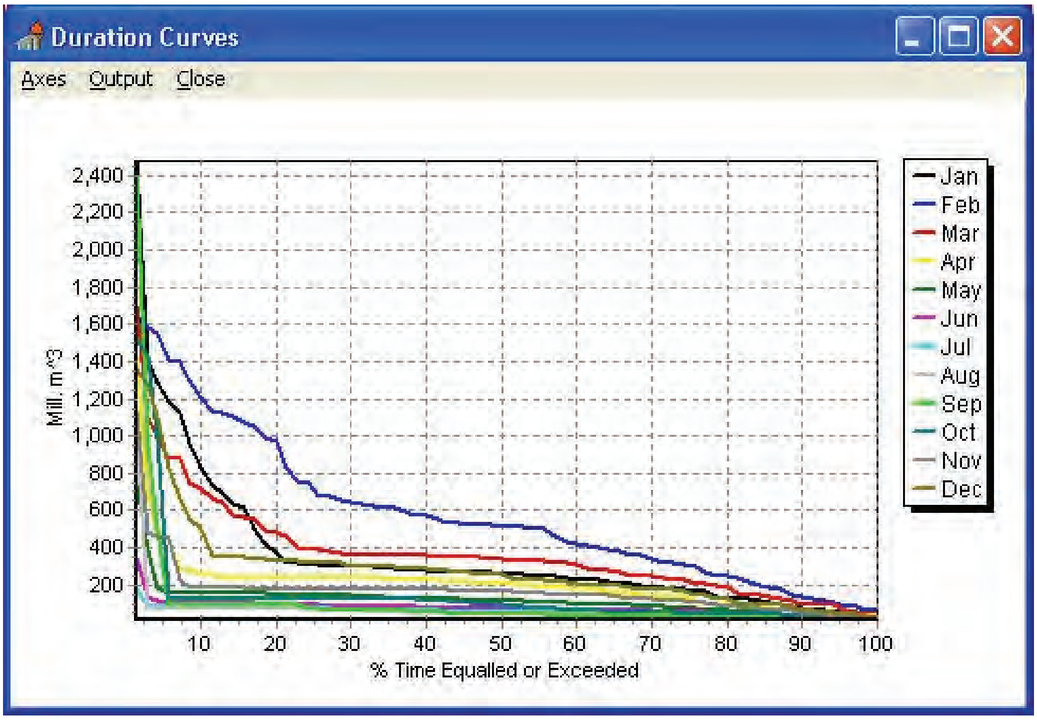


Figure 3.121 Example of the *Duration Curves* window in TSGraph

- *XY Plots* – The user is prompted to select a time series from the active graph to plot on the x-axis and a time series from the active graph to plot on the y-axis, these time series are then graphed as a scatter plot as shown in Figure 3.122. The user may choose to plot the actual or cumulative values for the time series. The graph may be printed or saved as an image in Windows Metafile (.*wmf*) format. In addition the user may choose for the following statistics to be calculated and displayed for natural and log values of the time series:

- Maximum for each time series
- Minimum for each time series
- Mean for each time series
- Standard deviation for each time series
- Coefficient of determination
- Coefficient of efficiency
- Number of data points

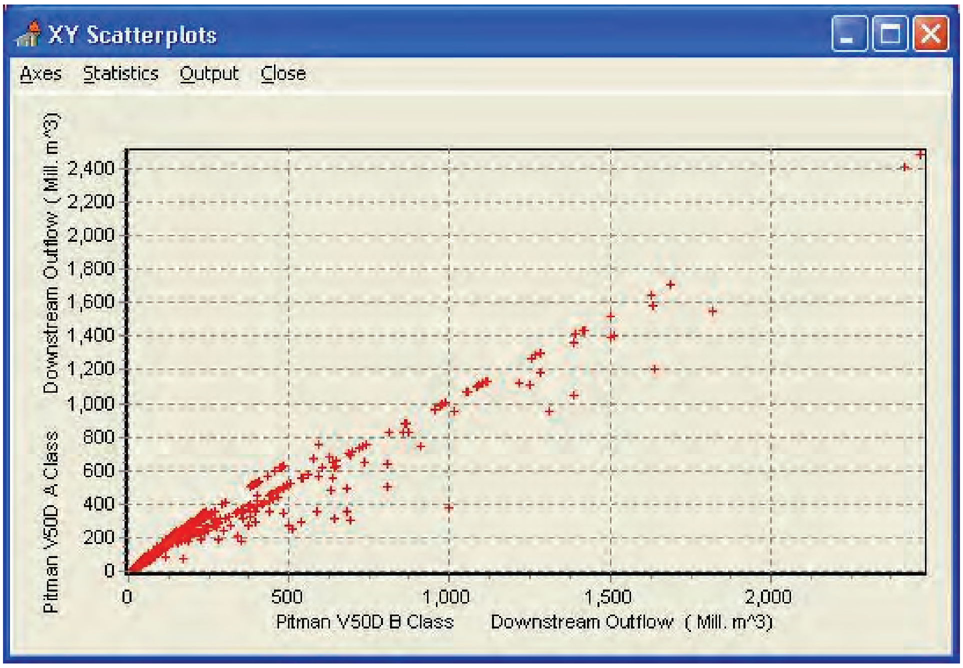


Figure 3.122 Example of the *XY Scatterplots* window in TSGraph

- *Baseflow* – The user is prompted to select a time series from the active graph for which to do a baseflow analysis. The user may select to do the baseflow analysis using either the digital filtering or rate of rise methods and is prompted to enter the relevant input parameters. The original time series and the calculated baseflow time series are plotted on a graph as shown in Figure 3.123. Clicking on the original time series on the graph will open a window displaying the mean of the total flow, the mean of the calculated baseflow and the percentage baseflow. The graph may be printed or saved as an image in Windows Metafile (.*wmf*) format.

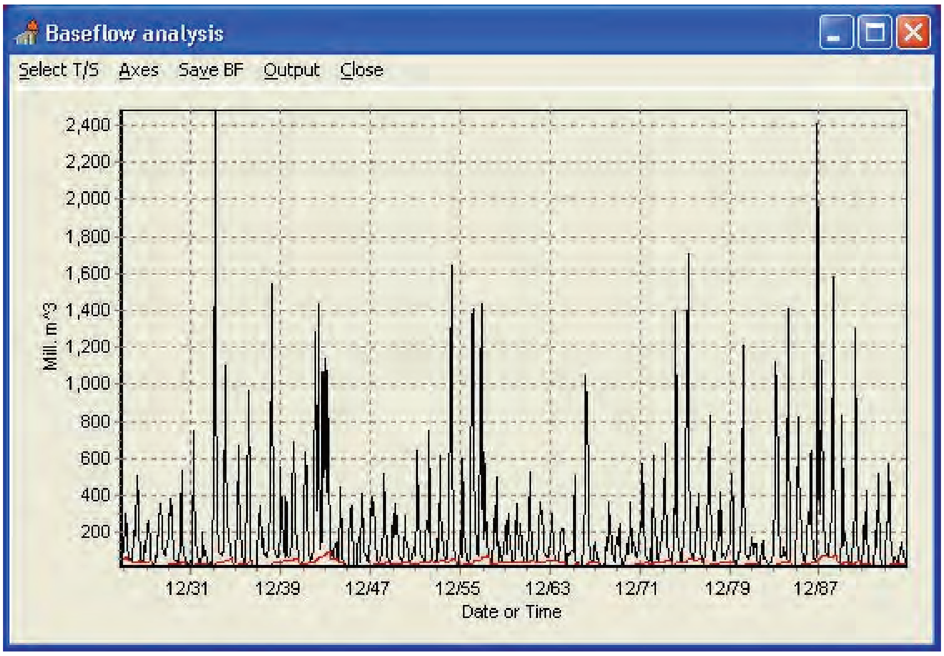


Figure 3.123 Example of the *Baseflow analysis* window in TSGraph

- *Run Analysis* – The user is prompted to select one or more time series from the active graph for which to do a run analysis. For each time series the user is prompted to specify a threshold value. The results of the run analysis are displayed as two graphs, one showing runs above the threshold value and one showing runs below the threshold value as shown in Figure 3.124.

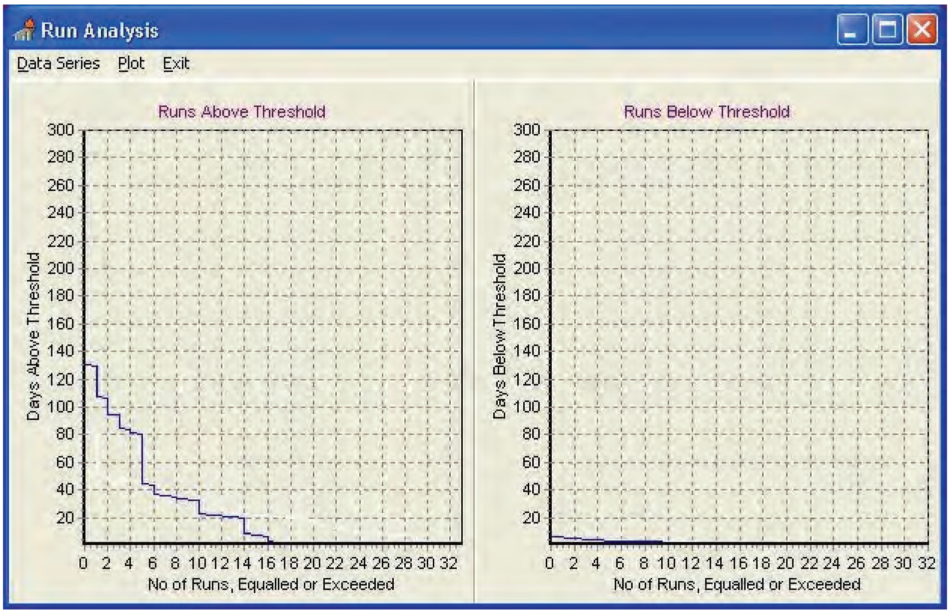


Figure 3.124 Example of the *Run Analysis* window in TSGraph

- *Transformation* – The user is prompted to select a time series from the active graph for which to do a transformation. The user may then load, edit and save a transformation matrix consisting of up to 20 corresponding raw data value and transformed data value pairs. After specifying the transformation matrix the user may plot the results of the transformation on a graph as shown in Figure

3.125. This transformation works by taking each value in the specified time series and calculating a new value by interpolation using the values in the transformation matrix. After plotting a transformation the user may save the transformation as a new time series in TSGraph which may then be plotted on one of the standard TSGraph graphs.

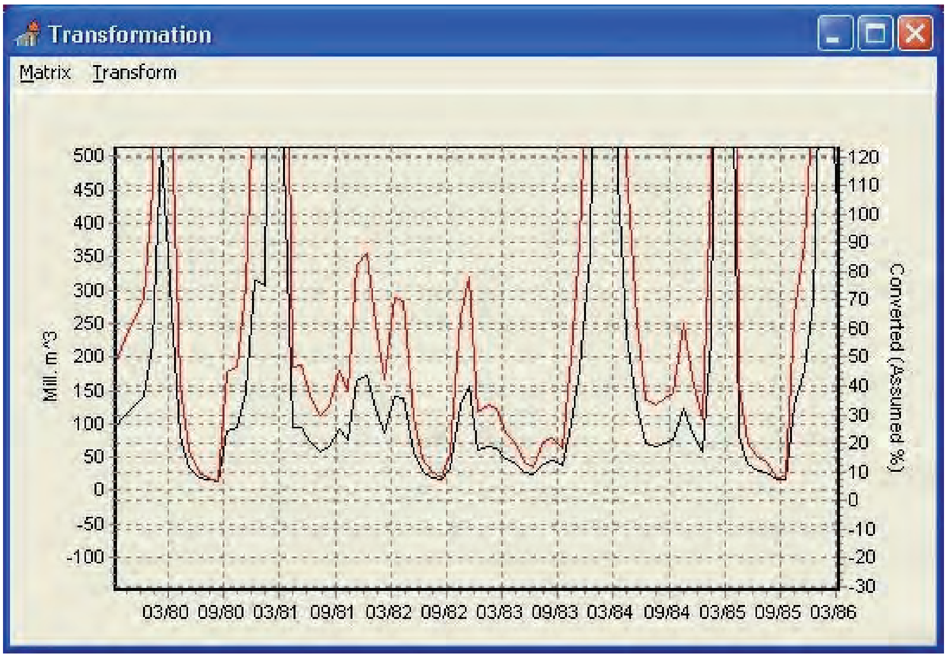


Figure 3.125 Example of the *Transformation* window in TSGraph

3.4 Running Models in SPATSIM-HDSF

Within the SPATSIM-HDSF modelling framework a selection of external models and data processing programs are provided for use. Each model is different, however, most of these models can be setup and run with the SPATSIM-HDSF framework in a generic manner. It is recommended that the user first understand the theory behind the specific model they wish to run before running the model from within SPATSIM-HDSF.

3.4.1 How to setup and run standard SPATSIM-HDSF Models

The method used to establish a specific application of an external model are the same for all the models and involve specifying and saving the details of the input data, output data and spatial elements to be modelled. This section describes how to setup and run a standard SPATSIM-HDSF model. The process is as follows:

- Select *Application->Setup Model->Select Spatial Objects* from the menu. There are three options and the one selected depends upon the type of model that is to be selected.

    - Select Spatial Element - This should be used for models that operate with single spatial elements (points or polygons) or unconnected groups of spatial elements. In this case the user simply clicks on all the required spatial elements until the list is complete. The currently selected Attribute is not important for this option.

- Identify Upstream Elements - This should be used for distributed, or semi-distributed, models where the sequence of spatial elements is of vital importance to the modelling approach. It is necessary to have an Attribute selected that is of type ‘Text’ and contains values from the selected *Desc.Field* in shape file specifying the next downstream spatial element. The lowest spatial element in the basin or catchment system is selected on the map and all upstream elements are identified automatically. If some of these are not required (i.e. the user wishes to exclude some upstream elements), clicking on another polygon will change the shading colour of all spatial elements above the one clicked and these will be coded for exclusion.

- Identify Downstream Elements - This option is similar to the previous option except that the identification process works in reverse and clicking a polygon causes all lower spatial elements to be identified, highlighted and listed. This is used where the model requires single links to be made along a channel (as in channel routing) and where the secondary tributary areas are not important.

- Once the spatial objects have been selected, click on *Select one or more spatial elements* button on the toolbar. This will bring up a list of models. Select the model required.

- A window as shown in Figure 3.126 will be displayed to enable the user to match a list of model variables and parameters with the available Attributes in the SPATSIM-HDSF project.

- Click on the *Save Requirements* button and the *Saving Application Process* window shown in Figure 3.127 will be displayed. Click on the *Finish* button.

- To run the model select *Application->Run Model* from the menu. This will bring up a list of models. Select, for example, the Pitman monthly model. The model specific window will appear and example window for the Pitman model is shown in Figure 3.128. Click on the *Read Data* button to run the model.

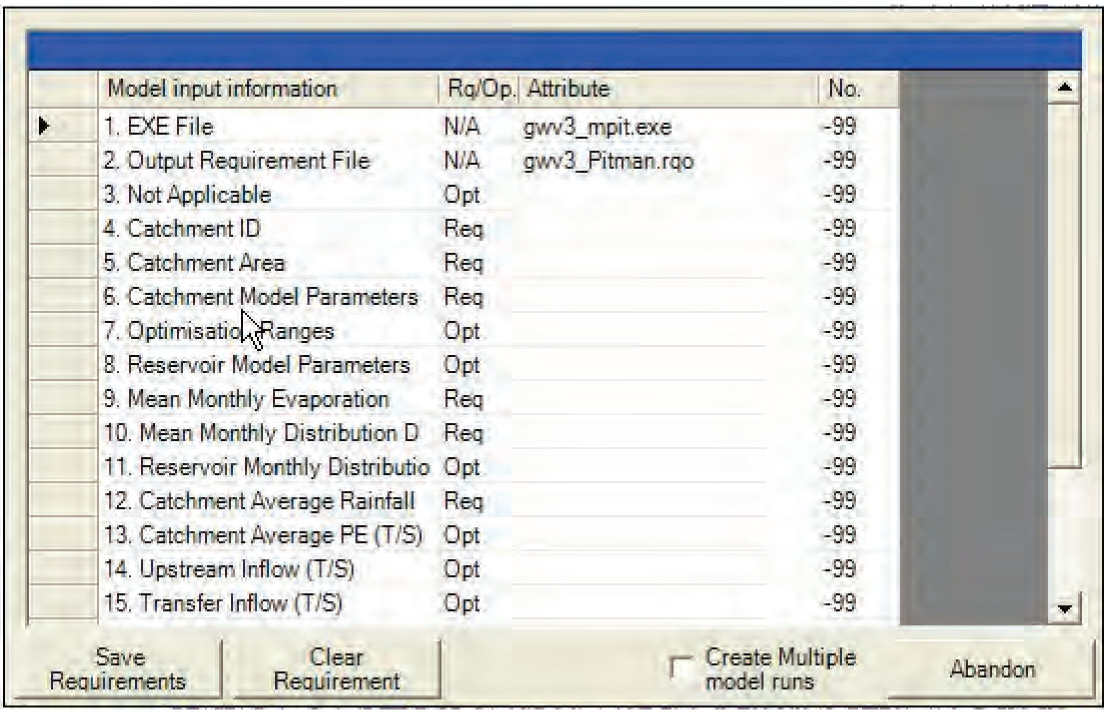


Figure 3.126 Window to capture data for a model setup

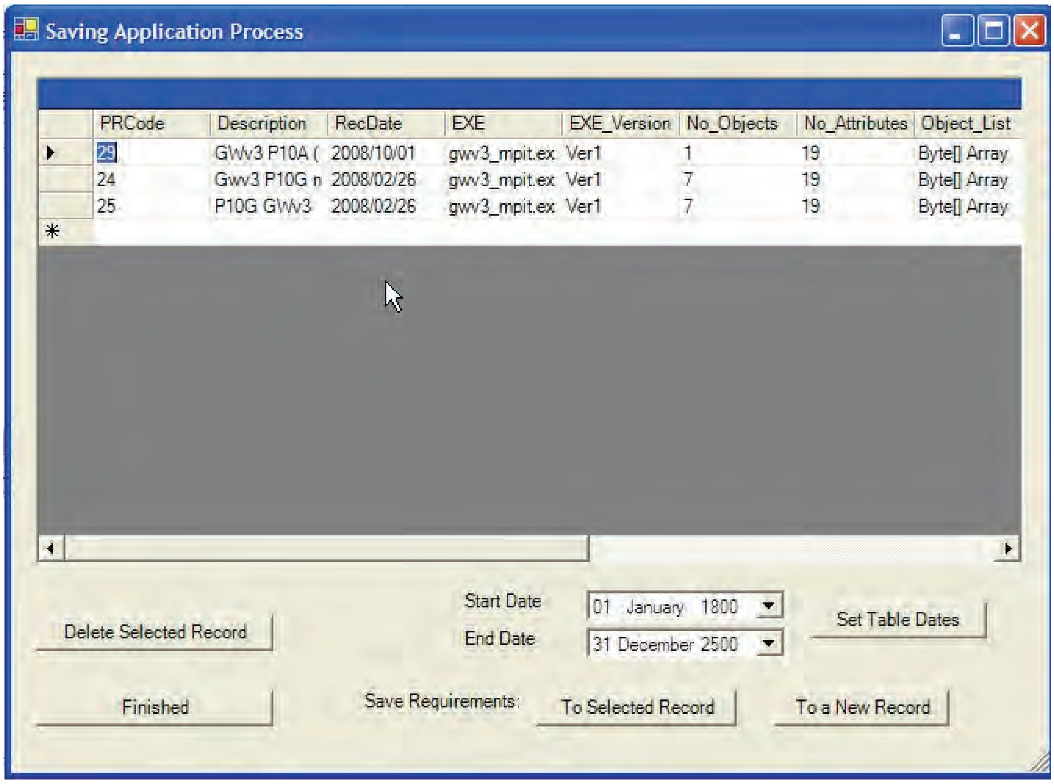


Figure 3.127 *Save Application Process* window

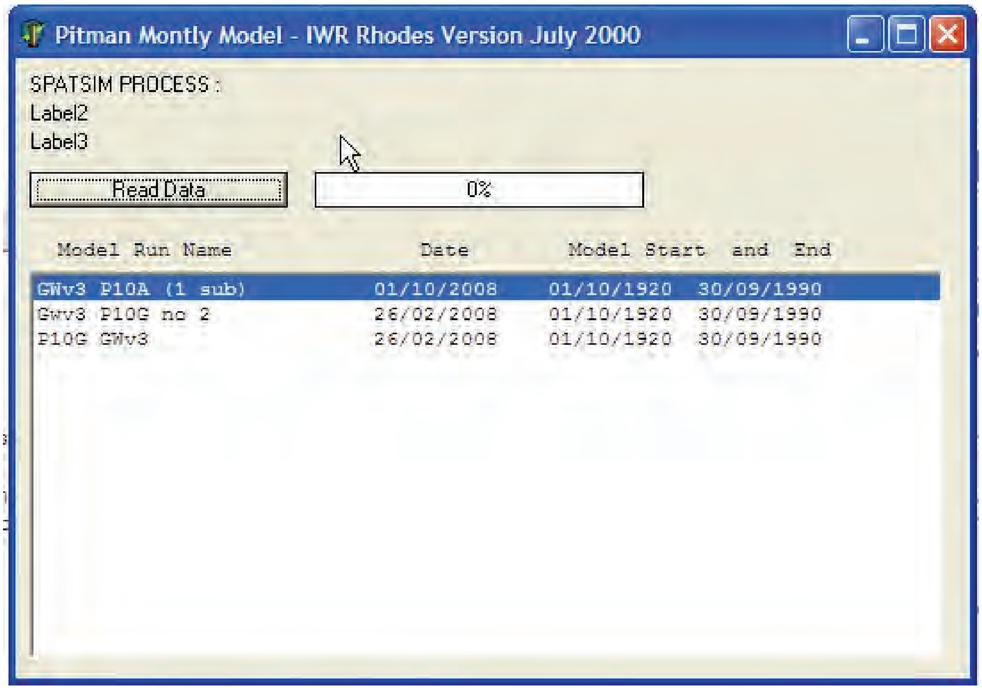


Figure 3.128 *Pitman Monthly Model*

3.4.2 How to run the ACRU Model and utilities

The *ACRU* agrohydrological model is a complex model with many model input variables and parameters. Due to the nature of the *ACRU* model it is not feasible to use the procedure to setup and run a model described above. The *ACRU* model and its related software utilities are accessed by selecting *Application->Run ACRU* from the menu. Detailed descriptions of how to setup and run the *ACRU* model and its utilities can be found in the *ACRU4 User Manual* (Thornton-Dibb *et al.,* 2010a) and the *Manual for Running the ACRU Model from SPATSIM-HDSF* (Thornton-Dibb *et al.,* 2010b).

4. SUPPORTED MODELS

During restructuring from the previous version of SPATSIM to the new HDSF version of SPATSIM it was considered important to convert the models that are most commonly used within SPATSIM (either by the IWR or by other users. The SPATSIM-HDSF compatible models currently available to be run from within the framework are briefly described in this section with references to sources of more detailed information about each model.

4.1 Desktop Parameter Calibration Model

This model reads information for all points in a Feature and checks to see if all the required data are available to define the type of Reserve determination that was carried out, the flow data that was used and the results of the determination. The model can then be used to display the results for a selection of sites against the default Desktop Reserve model parameter values. These can then be modified to better match the results of independent determinations.

For more information refer to the document *SPATSIM-HDSF National Database of Ecological Reserve and EWR Management* (Hughes *et al*., 2010) and the online help on the IWR website
[http://www.ru.ac.za/static/institutes/iwr/software/reserve/helpdss/model34.htm].

4.2 Desktop Reserve Model

This model is the widely used Desktop model for the ecological Reserve and is used by a number of DWA consultants as well as the IWR.

This is the Desktop Reserve model used to generate initial estimates of the quantity component of the ecological Reserve from sets of parameter values and a monthly time series of reference flows. The model can also be used with pre-defined BBM tables of IFR requirements to generate the assurance rules and time series of Reserve requirements during a more detailed Reserve determination. The model includes facilities for modifying all the default parameters so that it is appropriate to almost any level of Reserve determination where monthly flow data are the best available.

For more information refer to the document *SPATSIM-HDSF National Database of Ecological Reserve and EWR Management* (Hughes *et al*., 2010) and the online help on the IWR website
[http://www.ru.ac.za/static/institutes/iwr/software/reserve/helpdss/model33.htm].

4.3 Flow-Stressor Response Model

This model is also widely used by DWA consultants within the Reserve determination process (usually at intermediate and comprehensive levels).

For more information refer to the document *SPATSIM-HDSF National Database of Ecological Reserve and EWR Management* (Hughes *et al*., 2010).

4.4 The Ground Water Version 3 Pitman Monthly Model

This model is used frequently by the IWR for both research and practical purposes. In terms of the generation of simulated natural flows it is equivalent to the new version of the standard Pitman model used in WR2005. However, in the simulation of development effects (reservoirs, abstractions, etc.) it uses a different approach.

For more information refer to:
http://www.ru.ac.za/static/institutes/iwr/software/reserve/Pitman/road_map.htm
http://www.ru.ac.za/static/institutes/iwr/software/reserve/helpdss/model12.htm
http://www.ru.ac.za/static/institutes/iwr/software/reserve/Pitman/GW-SW-V3.htm

4.5 The Ground Water Version 3 Uncertainty Pitman Monthly Model

This is an uncertainty version of the Pitman model that includes the groundwater interaction components as developed by the IWR. The version allows for model parameters to be input as probability distributions rather than a set of single values. The model runs multiple times and generates ensemble outputs based on Monte Carlo random sampling from the parameter distributions.

For more information refer to:
http://www.ru.ac.za/static/institutes/iwr/

4.6 Pitman Model Parameter Exploration

This is the same version of the basic Pitman model but includes the input of range values and steps for selected parameters. The program then runs the model multiple times and generates objective functions (statistical comparisons between observed and simulated flows) for all the possible parameter combinations (using the specified step sizes within the specified range of parameter values). This program is used by the IWR to investigate parameter sensitivities and results uncertainty associated with the Pitman model.

For more information refer to:
http://www.ru.ac.za/static/institutes/iwr/software/reserve/helpdss/model12a.htm
http://www.ru.ac.za/static/institutes/iwr/software/reserve/Pitman/GW-SW-V3.htm

4.7 Real Time Reserve Management Model

The Real Time Reserve Management Model is described in Hughes *et al.* (2008)

4.8 Reserve Licensing Model linked to the Desktop Model

A model to be used with the output from the Desktop Reserve model to assess present day and future (licence applications) water resource developments in relatively small catchments with respect to Reserve requirements.

For more information refer to the document *SPATSIM-HDSF National Database of Ecological Reserve and EWR Management* (Hughes *et al*., 2010) and the online help on the IWR website http://www.ru.ac.za/static/institutes/iwr/software/reserve/helpdss/model39.htm

4.9 Satellite Daily Rainfall Capture Process

The Real Time Reserve Management Model is described in Hughes *et al.* (2008)

4.10 The *ACRU* Model

Models will be required by the CMAs to assist in the assessment and management of available water resources, water quality and groundwater and their dynamics within a catchment, and it is likely that a physical conceptual model operating at a daily timestep will be needed to adequately represent certain hydrological and operational processes for the fulfilment of some of these modelling requirements.

The *ACRU* model is a physical conceptual agrohydrological model that has been developed since the early 1970s in what is now the School of Bioresources Engineering and Environmental Hydrology at the University of KwaZulu-Natal and applied in South Africa. The *ACRU* model operates at a daily time step and is described in Schulze (1995) as a multi-purpose model which can be applied in design hydrology, crop yield modelling, reservoir yield simulation and irrigation water demand and supply, and assessment of climate change, land use and management impacts. The *ACRU* model has been applied extensively in South Africa, but also in other countries.

The input data requirements of the *ACRU* model are considerably larger than other models that run within the SPATSIM-HDSF modelling framework which lead to the development to the Configuration Editor software and the *ACRU*4 version of the model. Detailed descriptions of how to setup and run the *ACRU* model and its utilities can be found in the *ACRU4 User Manual* (Thornton-Dibb *et al.,* 2010a) and the *Manual for Running the ACRU Model from SPATSIM-HDSF* (Thornton-Dibb *et al.,* 2010b). For more details refer to the Manual for Running the ACRU Model from SPATSIM-HDSF by Thornton-Dibb *et al.* (2010a) and the *ACRU*4 User Manual by Thornton-Dibb *et al.* (2010b).

5. INFORMATION FOR DEVELOPERS

This chapter contains technical information about the SPATSIM-HDSF modelling framework software, database structure and associated software libraries. This technical information will be useful to software developers who may for example be developing a SPATSIM-HDSF model or modelling tool. This chapter is not intended for the average SPATSIM-HDSF user.

5.1 SPATSIM-HDSF Database Data Model

One of the most important criteria when selecting a framework for use in the HDSF project was the data model used by the framework. The design of the data model used in SPATSIM was based on the approach adopted by the Centre for Ecology and Hydrology (CEH) at Wallingford, United Kingdom (Hughes, 2002). One of the reasons for selecting SPATSIM was the data model used. The SPATSIM database data model was reviewed and extended taking into consideration the requirements of the HDSF project, including:

- Be extensible – adding new models and model variables must not require changes to the data model;
- Be generic – it must be suitable for application of a wide range of hydrology related models;
- Be object-oriented – it must enable storage of data in a manner suited to application with object-oriented models;
- Enable spatial and non-spatial components of the hydrological system to be represented;
- Enable linking of model variables to Attributes in multiple Features representing different components of the hydrological system;
- Store global model variables not related to components of the hydrological system;
- Represent relationships between components of hydrological system;
- Enable easy running of different scenarios, while avoiding unnecessary repetition of data;
- Enable storage of metadata about datasets and values;
- Store units of measure for all relevant data types; and
- Include the feasibility of linking to the ArcGIS geodatabase data model.

An entity relationship diagram of the SPATSIM-HDSF database data model is shown in Figure 5.1. Only some of the relationships between tables have been shown in Figure 5.1 in order to simplify the diagram. Descriptions, data types and other properties of the fields in each table in the SPATSIM-HDSF database data model are documented in Section 5.3.

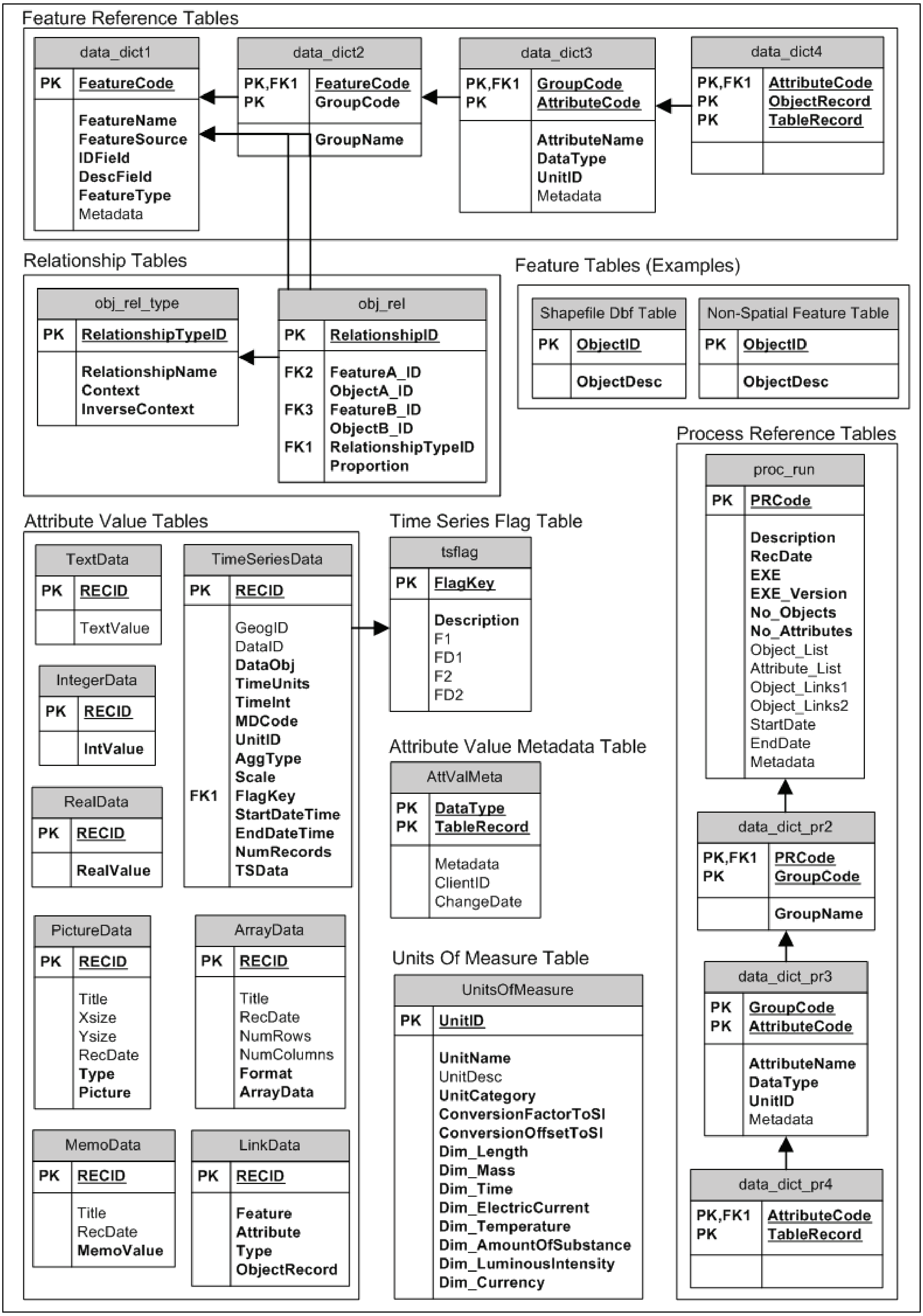


Figure 5.1 Entity relationship diagram of the SPATSIM-HDSF data model.

Spatial Features are represented by geographic data stored in ESRI shape files and a set of related Attributes stored in a SPATSIM-HDSF database. Each shape file used in SPATSIM-HDSF must have at least two fields in its Attribute table: one field containing a unique integer number for each Feature Object in the shape file and a second field containing a unique text string identifying each Feature Object. The data model makes provision for non-spatial Features to represent non-spatial components of the hydrological system, for example, water users. These non-spatial Features are represented by tables in a SPATSIM-HDSF database, one table for each type of non-spatial Feature to be represented.

The link between geographic data and Attribute data is achieved using four Feature reference tables stored in a SPATSIM-HDSF database. The *data_dict1* table stores a list of the spatial, non-spatial and image Features loaded for a project with references to the related ESRI shape files, non-spatial Feature tables or image files respectively. The *data_dict2* table stores a list of Attribute Groups and the Features to which they belong. The *data_dict3* table stores a list of Attributes and for each Attribute: the Attribute Group to which it belongs, the data type and the units of measure. The *data_dict4* table contains a cross-reference between Attributes, records in a shape file or non-spatial Feature table, and the corresponding record in the relevant Attribute value table. A unit of measure may be associated with each Attribute through a reference to a record in the *UnitsOfMeasure* table. The *UnitsOfMeasure* table contains a pre-defined fixed list of units of measure including dimensions, and conversion factor and offset values to enable conversion to SI units.

The database data model is designed such that there is a different Attribute value table for each of eight data types viz. Text, Integer, Real, Time Series, Picture, Array, Memo and Link. These Attribute value tables are named *TextData*, *IntegerData*, *RealData*, *TimeSeriesData*, *PictureData*, *ArrayData*, *MemoData* and *LinkData* respectively. The *TextData* table stores individual string data up to 256 characters. The *IntegerData* table stores individual signed 32-bit integer values. The *RealData* table stores individual 32-bit floating point values. The *TimeSeriesData* table stores a time series of 32-bit floating point values in a Binary Large Object (BLOB) in the *TSData* field, that is, each record in the *TimeSeriesData* table stores a whole time series. The other fields in the *TimeSeriesData* table store information describing the time series. Time series may be fixed interval or variable interval (break-point) and may contain data at a range of time intervals ranging from years to minutes. Data quality flags may also be associated with individual time series data values. Sets of data quality flags are stored in the *tsflag* table and references to these data quality flags are stored together with the time series data values in the *TSData* field of the *TimeSeriesData* table. The *PictureData* table enables the storage of pictures in a range of different formats as a BLOB. The *ArrayData* table enables the storage of two-dimensional arrays of 32-bit floating point values in a BLOB in the *ArrayData* field, with a reference to a text file containing information about the array. The *MemoData* table stores large string datasets that are too big for the *TextData* table. The *LinkData* table enables the storage of links to other Attribute values already stored for other Attributes, for the purpose of preventing the repetition of data in a SPATSIM-HDSF database, especially large time series datasets. The *AttValMeta* table stores metadata for individual Attribute values referenced by Attribute value table and record.

One of the requirements for the SPATSIM-HDSF data model is that it should enable the storage of relationships between components of hydrological system, that is, relationships between objects in the same or different Features. For example, it would be useful to be able to specify a representative rain gauge for each catchment being modelled. Components of the hydrological system do not exist in isolation from each other, but are interrelated to window a complex system. Relationships are important in modelling complex hydrological systems and the *obj_rel* and *obj_rel_type* tables have been included in the data model as a simple means of representing these relationships. The purpose of the *obj_rel_type* table is to store a set of relationship types, for example, a "streamflow" relationship type where the context is "is downstream of" and the inverse context is "is upstream of". The purpose of the *obj_rel* table is to store individual relationships of a specified relationship type between two specified components of the hydrological system being modelled.

The SPATSIM-HDSF software is designed with the goal of enabling a number of SPATSIM-HDSF compatible models to be run from within a common modelling environment. However, other modelling software utilities may also be run from SPATSIM-HDSF, and the SPATSIM-HDSF compatible models and utilities are collectively referred to in SPATSIM-HDSF as processes. Each time a process is run within SPATSIM-HDSF the user is required to specify necessary data related to the run in a record of the *proc_run* table. To facilitate the storage of additional information about individual process runs, for example, model options and descriptions of the scenarios run, a set of process Attribute Groups and Attributes may be setup. These process Attribute Groups and Attributes work in a similar manner to the Feature Attribute Groups and Attributes. The *data_dict_pr2* table stores a list of process Attribute Groups and the process runs to which they belong. The *data_dict_pr3* table stores a list of process Attributes and for each process Attribute Group. The *data_dict_pr4* table contains a cross-reference between process Attributes and the corresponding record in the relevant Attribute value table. The process Attribute values are stored in the same set of Attribute value tables as the Feature Attribute values. Link type Attributes are not permitted for process Attributes.

The SPATSIM-HDSF database data model has been designed to be extensible such that model parameters for any SPATSIM-HDSF compatible model may be stored. To aid the developers of the SPATSIM-HDSF software and developers of SPATSIM-HDSF compatible models a set of data access classes has been created.

The further development of the internal GIS tools required the addition of the *FeatureTheme* table to the data model to enable the storage of display information for each theme associate with a Feature in the *data_dict1* table. The external GIS tools developed within this project required the addition of the *ETBaseData* and *ETAutoCalc* tables to the data model. The *ETBaseData* table stores information about basedata coverages and GRIDs which is then available for use in the auto calculation functions. The *ETAutoCalc* table stores information relating a grid contained in the *ETBaseData* table (ETBaseDataID) and an Attribute in the *data_dict3* table (AttributeCode) into which summary information will be placed. An entity relationship diagram of these GIS related tables in the SPATSIM-HDSF database data model is shown in Figure 5.2. Descriptions, data types and other properties of the fields in each table are documented in Section 5.3.

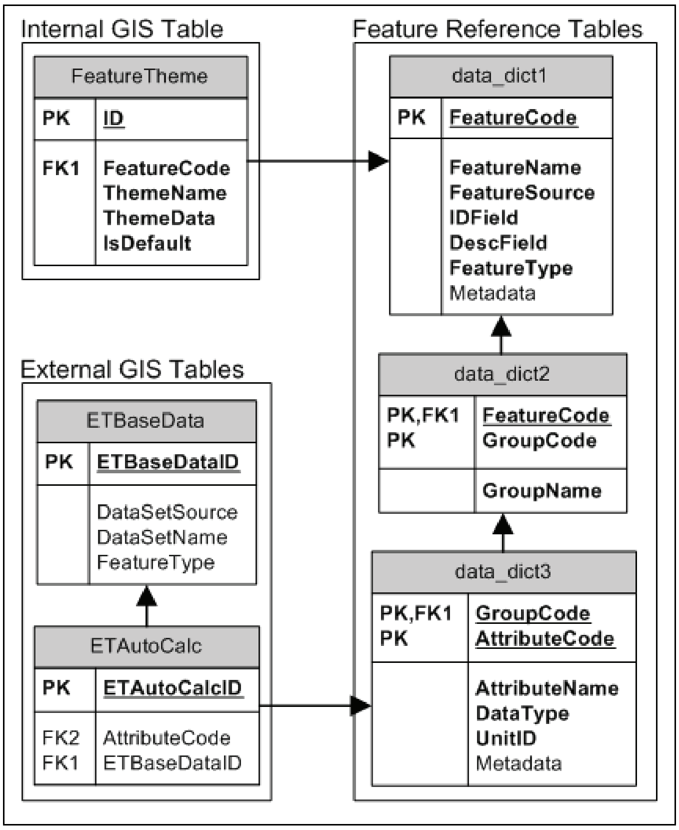


Figure 5.2 Entity relationship diagram of GIS related tables in SPATSIM-HDSF data model.

The folder structure for SPATSIM-HDSF is shown in Figure 5.3. When the SPATSIM-HDSF software is installed a folder named *hdsf* is created on the user's hard drive. The initialisation file (.ini) for each SPATSIM-HDSF project is stored in the *hdsf* folder. The sub-folder named *bin* contains executable files for models and utility software to be run from SPATSIM-HDSF. The *Docs* folder contains documentation files for models to be run from SPATSIM-HDSF. The folder named *export* is the folder to which SPATSIM-HDSF data export files are saved. The *text_data* folder contains text files with *.req*, *.rqo*, *.txo* and *.txp* extensions and other files used by SPATSIM-HDSF to define model requirements, model output and array formats. The *Access_example* folder is an example of a SPATSIM-HDSF project folder, which typically contains three subfolders named *cover*, *data* and *dbdata*. The *cover* folder contains shapefile files. The *data* folder may contain data input files and SPATSIM-HDSF data output files. The *dbdata* folder contains the SPATSIM-HDSF database files.

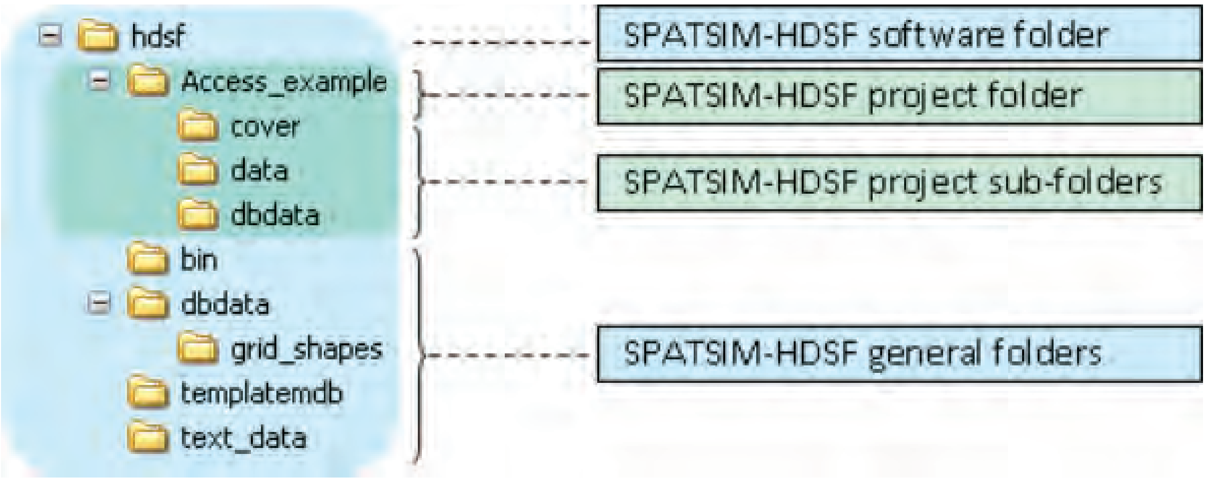


Figure 5.3 Folder structure for SPATSIM-HDSF.

5.2 Data Access Classes

An important part of the implementation of theSPATSIM-HDSF database data model is the development of a set of classes containing standard SPATSIM-HDSF project database access methods to create, populate, edit and query SPATSIM-HDSF databases. These SPATSIM-HDSF project database access methods will simplify database access not only in SPATSIM-HDSF, but also in the models modified to run from within the SPATSIM-HDSF framework. These classes were initially developed in the Delphi for .Net programming language and are packaged as a Dynamic Link Library (DLL) which can be used in code written in any .Net programming language. However, there are many legacy models written in a variety of programming languages that would not be able to utilise these .Net compliant classes; therefore, a similar set of Component Object Model (COM) accessible classes was developed. Further to this, there may be models such as the *ACRU* model which are written in the Java programming language. Technically it is possible to access COM objects and .Net classes in a DLL from Java code using the Java Native Interface (JNI), however, in practice this was found to be difficult. Therefore, a Java version of the data access classes was created to simplify use of these classes in Java code and provide better run-time performance. As far as possible these database access classes are based on standard Structured Query Language (SQL) queries to facilitate possible use with a selection of relational database management systems (RDBMSs).

.Net and COM Version

A Universal Modelling Language (UML) diagram of the .Net version of the SPATSIM-HDSF data access classes is shown in Figure 5.4. The namespace *Spatsim* was selected as the main namespace and the namespace *Spatsim.Data* was created under this to contain the data access classes developed. The *Spatsim.Data* namespace contains the namespaces *ADO_Ole*, *COM* and *Exceptions* and three classes *IniInfo*, *TSInfo* and *ArrayInfo*. The data access classes have been developed using ADO.Net database components and OleDb data providers. The two main data access classes *DataAccess* and *Database* have been created in the *Spatsim.Data.ADO_Ole* namespace. The classes in the *Spatsim.Data.ADO_Ole* namespace and all the classes on which they depend have been compiled into a .Net accessible DLL named *SPATSIM_DataAccess_DotNet.dll*. The *Spatsim.Data.COM* namespace contains COM accessible versions of the *DataAccess*, *IniInfo*, *TSInfo* and *ArrayInfo* classes. The classes in the Spatsim.Data.COM namespace and all the classes on which they depend have been compiled into a separate COM accessible DLL named *SPATSIM_DataAccess_COM.dll*. The *Spatsim.Data.Exceptions* contains a set of Exception classes used in the data access classes. The classes in the *SPATSIM_DataAccess_DotNet.dll* and *SPATSIM_DataAccess_COM.dll* libraries are supported by documentation in Hypertext Markup Language (HTML) format.

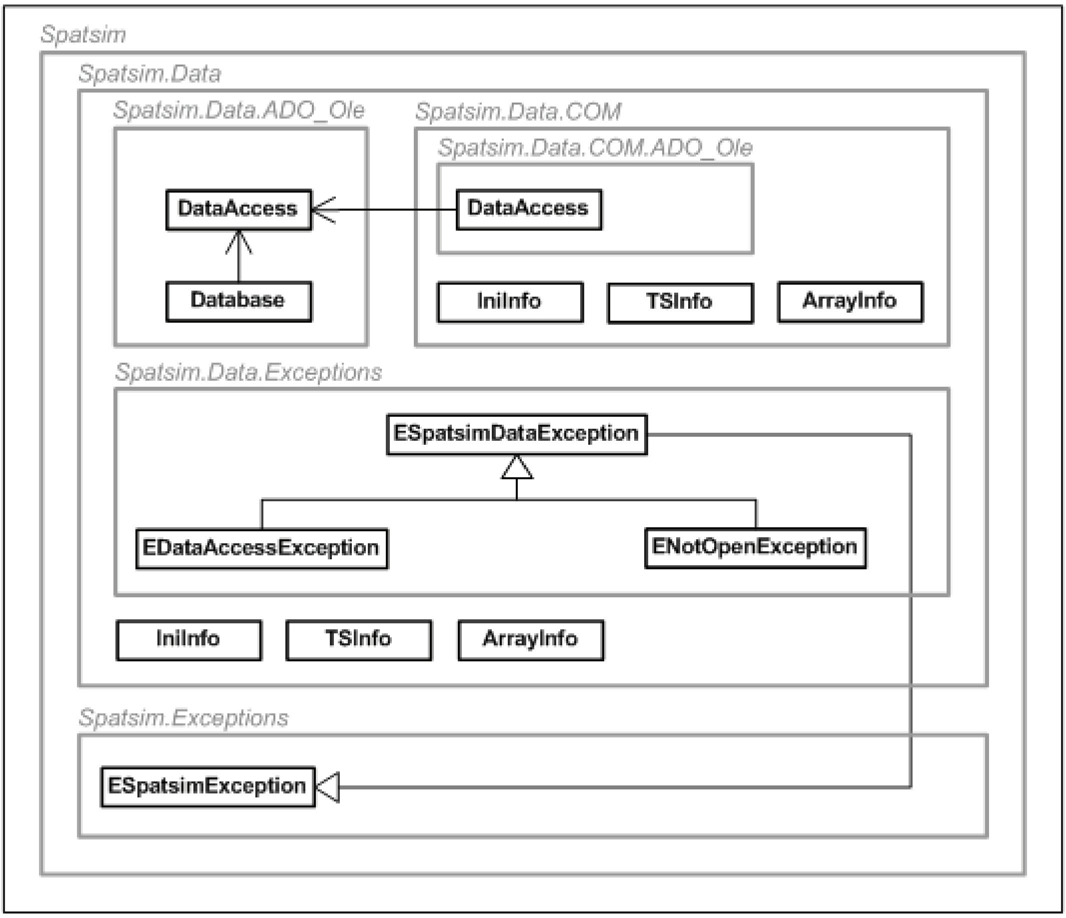


Figure 5.4 UML diagram of the .Net version of the SPATSIM-HDSF data access classes.

The *DataAccess* class in the *Spatsim.Data.ADO_Ole* namespace is the core of the set of data access classes developed. This *DataAccess* class contains a comprehensive set of over 250 methods to perform the following operations on a SPATSIM-HDSF database:

- connect to a specified database,
- create tables in a new database,
- return SQL query strings to query a database,
- insert new records into a database,
- update existing records in a database, and
- delete records from a database.

The *Database* class in the *Spatsim.Data.ADO_Ole* namespace is a wrapper around the *DataAccess* class. This ADO.Net specific *Database* class contains an almost identical set of methods to those in the *DataAccess* class with the difference that for each of the methods in the *DataAccess* class which return SQL query strings the corresponding methods in the *Database* class return a *System.Data.DataTable* object containing a result set returned by the SQL query.

The *IniInfo* class in the *Spatsim.Data* namespace contains a set of methods to read, query, modify and write the project initialisation information contained in SPATSIM-HDSF project initialisation files. The *TSInfo* class in the *Spatsim.Data* namespace contains a set of methods to read, query, modify and write the time series data stored in the *TSData* BLOB field in the *TimeSeriesData* Attribute value data table. Instances of the *TSInfo* class should be used in conjunction with the *Database* class to work with time series data stored in SPATSIM-HDSF databases. The *ArrayInfo* class in the *Spatsim.Data* namespace contains a set of methods to read, query, modify and write the array data stored in the *ArrayData* BLOB field in the *ArrayData* Attribute value data table. Instances of the *ArrayInfo* class should be used in conjunction with the *Database* class to work with array data stored in SPATSIM-HDSF databases.

The *DataAccess* class in the *Spatsim.Data.COM.ADO_Ole* namespace is a wrapper around the *Spatsim.Data.ADO_Ole.DataAccess* class and contains an almost identical set of methods to those in the *Spatsim.Data.ADO_Ole.DataAccess* class. As COM does not support overloading of method names the method names in the *Spatsim.Data.COM.ADO_Ole.DataAccess* classes have been modified with a suffix (e.g. "_1") to make each method name unique. Similarly the *IniInfo*, *TSInfo* and *ArrayInfo* classes in the *Spatsim.Data.COM* namespace are wrappers around the *IniInfo*, *TSInfo* and *ArrayInfo* classes in the *Spatsim.Data* namespace.

Java Version

A UML diagram of the Java version of the SPATSIM-HDSF data access classes is shown in Figure 5.5. The classes in the Java version of the SPATSIM-HDSF data access classes are very similar to their equivalent classes in the .Net version. The namespace *Spatsim* was selected as the main namespace and a namespace *Spatsim.Data* was created under this to contain the data access objects developed. The *Spatsim.Data* namespace contains the namespaces *JDBC* and *Exceptions* and two classes *IniInfo* and *TSInfo*. The Java version of the data access objects have been developed using the Java DataBase Connectivity (JDBC) database components. The two main data access objects *DataAccess* and *Database* have been created in the *Spatsim.Data.JDBC* namespace. The *Spatsim.Data.Exceptions* namespace contains a set of Exception classes used in the data access objects. All the classes shown in Figure 5.5 have been packaged into a Java archive file named *Spatsim_DataAccess_Java.jar*. The Java data access classes and their methods are supported by documentation in HTML format. When using the *DataAccess* and *Database* classes a driver specific to the RDBMS may be used if available otherwise the standard JDBC-ODBC drivers may be used.

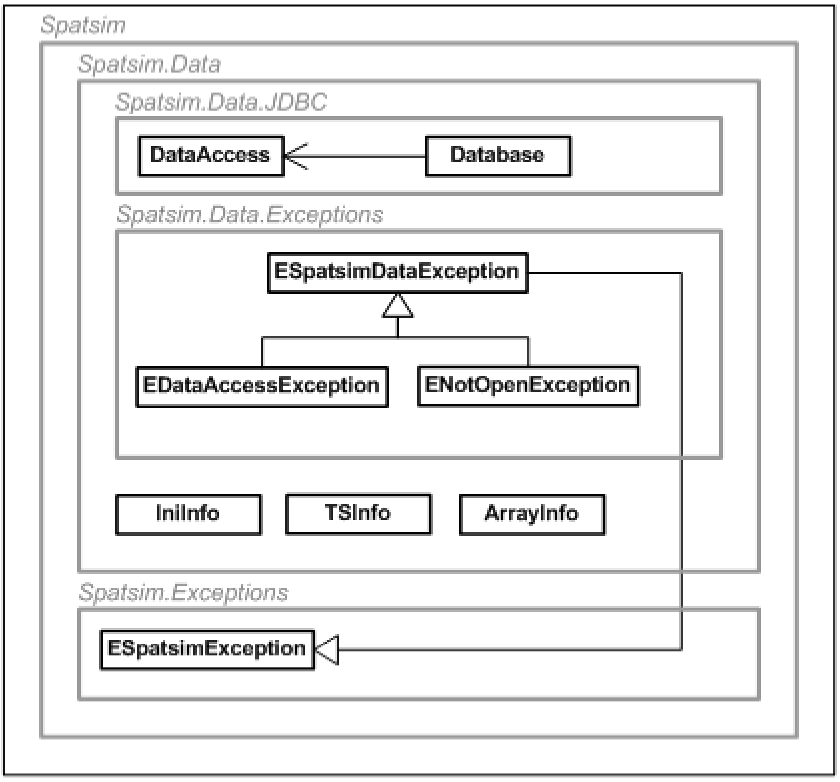


Figure 5.5 UML diagram of the Java version of the SPATSIM-HDSF data access classes.

The development of the .Net, COM and Java versions of data access classes took a considerable amount of time and work, however, it is expected that these classes will be invaluable not only to the developers of the SPATSIM-HDSF framework but more importantly to anyone wanting to modify a model or modelling utility to run within the SPATSIM-HDSF modelling framework.

5.3 Specifications for the SPATSIM-HDSF Data Model

Table 5-1 Description of data types

Data Type	Description
COUNTER	Auto-incrementing 32-bit integer counter field
SMALLINT	16-bit integer field
INTEGER	32-bit integer field
DOUBLE	Double precision floating-point number field (15 digit precision)
VARCHAR(n)	String field. Maximum size of n characters where n < 255
LONGCHAR	String field up to 2.0 Gigabytes
LONGBINARY	Binary field up to 2.0 Gigabytes
DATETIME	Date and time field
BOOLEAN	Boolean field (1 bit)

Feature Reference Table: *data_dict1*

Table 5-2 Description of the fields in the *data_dict1* table (after Hughes, 2005; IWR, 2005)

Field	Description
FeatureCode	A unique ID number associated with a single Feature (shape file).
FeatureName	The name of the Feature for display and selection purposes.
FeatureSource	The path and filename of an ESRI shape file, image or the name of a *NonSpatialFeatureTable* table.
IDField	The field name in the shape file or *NonSpatialFeatureTable* table that uniquely identifies an Object (integer data).
DescField	The field name in the shape file or *NonSpatialFeatureTable* table that is selected to describe the objects (text or number data).
FeatureType	An integer number identifying the type of Feature: 1 = Spatial, 2 = Image, 3 = Non-spatial, 4 = GRID.
Metadata	A memo field in which metadata describing the Feature may be recorded.

Table 5-3 Specifications for the *data_dict1* table

Field	Type	Primary Key	Required	Maximum Value	Minimum Value	Default Value
FeatureCode	COUNTER	✓	✓			
FeatureName	VARCHAR (40)		✓			
FeatureSource	VARCHAR (100)		✓			
IDField	VARCHAR (40)		✓			
DescField	VARCHAR (40)		✓			
FeatureType	SMALLINT		✓			
Metadata	LONGCHAR					

Feature Table: NonSpatialFeatureTable

Table 5-4 Description of the fields in a *NonSpatialFeatureTable* table

Field	Description
ObjectID	A unique integer ID used to identify the non-spatial Object.
ObjectDesc	A unique text name describing the non-spatial Object.

Table 5-5 Specifications for a *NonSpatialFeature* table

Field	Type	Primary Key	Required	Maximum Value	Minimum Value	Default Value
ObjectID	COUNTER	✓	✓			
ObjectDesc	VARCHAR (80)		✓			

Feature Reference Table: *data_dict2*

Table 5-6 Description of the fields in the *data_dict2* table

Field	Description
FeatureCode	A unique ID number associated with a single Feature. References the *FeatureCode* field in the *data_dict1* table.
GroupCode	A unique ID number associated with an Attribute Group.
GroupName	The name of an Attribute Group.

Table 5-7 Specifications for the *data_dict2* table

Field	Type	Primary Key	Required	Maximum Value	Minimum Value	Default Value
FeatureCode	INTEGER	✓	✓			
GroupCode	COUNTER	✓	✓			
GroupName	VARCHAR (30)		✓			

Feature Reference Table: *data_dict3*

Table 5-8 Description of the fields in the *data_dict3* table (after Hughes, 2005; IWR, 2005)

Field	Description
GroupCode	A unique ID number associated with an Attribute Group. References the *GroupCode* field in the *data_dict2* table.
AttributeCode	A unique ID number associated with the Attribute.
AttributeName	The name of the Attribute associated with the Feature.
DataType	An integer number identifying the type of data associated with the Attribute that also defines the type of Attribute data table that the Attribute data will be stored in. The data types are: 0 = Text, 1 = Integer, 2 = Real, 3 = Time Series, 4 = Picture, 5 = Array, 6 = Memo, 7 = Link.
UnitID	A unique ID number associated with the unit of measure. References the *UnitID* field in the *UnitsOfMeasure* table.
Metadata	A memo field in which metadata describing the Attribute may be recorded.

Table 5-9 Specifications for the *data_dict3* table

Field	Type	Primary Key	Required	Maximum Value	Minimum Value	Default Value
GroupCode	INTEGER	✓	✓			
AttributeCode	COUNTER	✓	✓			
AttributeName	VARCHAR (30)		✓			
DataType	SMALLINT		✓			
UnitID	INTEGER		✓			
Metadata	LONGCHAR					

Feature Reference Table: *data_dict4*

Table 5-10 Description of the fields in the *data_dict4* table (after Hughes, 2005; IWR, 2005)

Field	Description
AttributeCode	A unique ID number associated with the Attribute. References the *AttributeCode* field in the *data_dict3* table.
ObjectRecord	A unique ID number associated with an Object of the relevant Feature. References the Object*ID* field in the relevant Feature's *ShapefileDbfTable* or *NonSpatialFeatureTable* table.
TableRecord	A unique ID number associated with the Attribute data for the Attribute. References the *RECID* field of the Attribute data table associated with the Attribute.

Table 5-11 Specifications for the *data_dict4* table

Field	Type	Primary Key	Required	Maximum Value	Minimum Value	Default Value
AttributeCode	INTEGER	✓	✓			
ObjectRecord	INTEGER	✓	✓			
TableRecord	INTEGER	✓	✓			

Attribute Value Metadata Table: *AttValMeta*

Table 5-12 Description of the fields in the *AttValMeta* table

Field	Description
TableCode	A unique ID number associated with each Attribute data table. References the *TableCode* field in the *data_dict5* table.
TableRecord	A unique ID number associated with the Attribute data for the Attribute. References the *RECID* field of the Attribute data table associated with each Attribute.
Metadata	A memo field in which metadata describing an Attribute value may be recorded.
ClientID	The ID of the client (SPATSIM-HDSF user) who added or made changes to the referenced Attribute value
ChangeDate	The date that the referenced Attribute value was added or changed

Table 5-13 Specifications for the *AttValMeta* table

Field	Type	Primary Key	Required	Maximum Value	Minimum Value	Default Value
DataType	SMALLINT	✓	✓			
TableRecord	INTEGER	✓	✓			
Metadata	LONGCHAR					
ClientID	VARCHAR (20)					
ChangeDate	DATETIME					

Process Reference Table: *proc_run*

Table 5-14 Description of the fields in the *proc_run* table

Field	Description
PRCode	A unique ID number associated with each model application.
Description	A description of the model application.
RecDate	The date on which the model application was created or last edited.
EXE	The name of the model's executable file.
EXE_Version	The version number of the model.
No_Objects	The number of Feature objects included in the modelling application.
No_Attributes	The number of Feature Attributes included in the modelling application.
Object_List	A list of the objects (and the Features they belong to) included in the modelling application.
Attribute_List	A list of the Attributes (and the Features they belong to) included in the modelling application.
Object_Links1	A list of object links.
Object_Links2	A second list of object links.
StartDate	The simulation start date for the model application.
EndDate	The simulation end date for the model application.
Metadata	A memo field in which metadata describing a model application may be recorded.

Table 5-15 Specifications for the *proc_run* table

Field	Type	Primary Key	Required	Maximum Value	Minimum Value	Default Value
PRCode	COUNTER	✓	✓			
Description	VARCHAR (40)		✓			
RecDate	DATETIME		✓			
EXE	VARCHAR (40)		✓			
EXE_Version	VARCHAR (30)		✓			
No_Objects	SMALLINT		✓			
No_Attributes	SMALLINT		✓			
Object_List	LONGBINARY					
Attribute_List	LONGBINARY					
Object_Links1	LONGBINARY					
Object_Links1	LONGBINARY					
StartDate	DATETIME					
EndDate	DATETIME					
Metadata	LONGCHAR					

Process Reference Table: *data_dict_pr2*

Table 5-16 Description of the fields in the *data_dict_pr3* table

Field	Description
PRCode	A unique ID number associated with a model application. References the *PRCode* field in the *proc_run* table.
GroupCode	A unique ID number associated with the Attribute Group.
GroupName	The name of the Attribute Group associated with a model application.

Table 5-17 Specifications for the *data_dict_pr2* table

Field	Type	Primary Key	Required	Maximum Value	Minimum Value	Default Value
PRCode	INTEGER	✓	✓			
GroupCode	COUNTER	✓	✓			
GroupName	VARCHAR (30)		✓			

Process Reference Table: *data_dict_pr3*

Table 5-18 Description of the fields in the *data_dict_pr3* table

Field	Description
GroupCode	A unique ID number associated with an Attribute Group. References the *GroupCode* field in the *data_dict_pr3* table.
AttributeCode	A unique ID number associated with the Attribute.
AttributeName	The name of the Attribute associated with a model application.
DataType	An integer number identifying the type of data associated with the Attribute that also defines the type of Attribute data table that the Attribute data will be stored in. The data types are: 0 = Text, 1 = Integer, 2 = Real, 3 = Time Series, 4 = Bitmap (Graphic), 5 = Array, 6 = Memo, 7 = Link.
UnitID	A unique ID number associated with the unit of measure. References the *UnitID* field in the *UnitsOfMeasure* table.
Metadata	A memo field in which metadata describing the Attribute may be recorded.

Table 5-19 Specifications for the *data_dict_pr3* table

Field	Type	Primary Key	Required	Maximum Value	Minimum Value	Default Value
GroupCode	INTEGER	✓	✓			
AttributeCode	COUNTER	✓	✓			
AttributeName	VARCHAR (30)		✓			
Datatype	SMALLINT		✓			
UnitID	INTEGER		✓			
Metadata	LONGCHAR					

Process Reference Table: *data_dict_pr4*

Table 5-20 Description of the fields in the *data_dict_pr4* table

Field	Description
AttributeCode	A unique ID number associated with the Attribute. References the *AttributeCode* field in the *data_dict_pr3* table.
TableRecord	A unique ID number associated with the Attribute data for the Attribute. References the *RECID* field of the Attribute data table associated with the Attribute.

Table 5-21 Specifications for the *data_dict_pr4* table

Field	Type	Primary Key	Required	Maximum Value	Minimum Value	Default Value
AttributeCode	INTEGER	✓	✓			
TableRecord	INTEGER	✓	✓			

Relationship Table: *obj_rel*

Table 5-22 Description of the fields in the *obj_rel* table

Field	Description
RelationshipID	A unique ID number associated with the relationship.
FeatureA_ID	A unique ID number associated with the Feature containing Object A of the relationship. References the *FeatureCode* field in the *data_dict1* table.
ObjectA_ID	A unique ID number associated with Object A of the relationship. References the *ObjectID* field in the relevant Feature's *ShapefileDbfTable* table.
FeatureB_ID	A unique ID number associated with the Feature containing Object B of the relationship. References the *FeatureCode* field in the *data_dict1* table.
ObjectB_ID	A unique ID number associated with Object B of the relationship. References the *ObjectID* field in the relevant Feature's *ShapefileDbfTable* table.
RelationshipTypeID	A unique ID number associated with the relationship type. References the *RelationshipTypeID* field in the *obj_rel_type* table.
Proportion	A proportion value that can be applied to the relationship between Object A and Object B where Object A has the same type of relationship with two or more other objects.

Table 5-23 Specifications for the o*bj_rel* table

Field	Type	Primary Key	Required	Maximum Value	Minimum Value	Default Value
RelationshipID	COUNTER	✓	✓			
FeatureA_ID	INTEGER					
ObjectA_ID	INTEGER					
FeatureB_ID	INTEGER					
ObjectB_ID	INTEGER					
RelationshipTypeID	INTEGER					
Proportion	DOUBLE					1.0

Relationship Table: *obj_rel_type*

Table 5-24 Description of the fields in the *obj_rel_type* table

Field	Description
RelationshipTypeID	A unique ID number associated with the relationship type.
RelationshipName	The name of the relationship.
Context	A description of the context of the relationship.
InverseContext	A description of the inverse of the context of the relationship.

Table 5-25 Specifications for the o*bj_rel_type* table

Field	Type	Primary Key	Required	Maximum Value	Minimum Value	Default Value
RelationshipTypeID	+	✓	✓			
RelationshipName	VARCHAR (40)		✓			
Context	VARCHAR (40)		✓			
InverseContext	VARCHAR (40)		✓			

Units Of Measure Table: *UnitsOfMeasure*

A system of units of measure has been implemented in SPATSIM-HDSF. This system refers to units and dimensions, where a unit has a magnitude and can be used to measure things and a dimension describes the type of thing being measured. In the SI system there are seven base dimensions of measure as shown in

Table 5-26 and currency has been added as additional dimension. A unit of measure is described by its dimensions, a conversion factor to SI units and a conversion offset to SI units. For a given value the conversion to an SI value is done using Equation 1.

Table 5-26 Base dimensions and units used in OpenMI (after HarmonIT (2005c))

Dimension Base	SI Base Unit	Symbol Used
Length	meter	m
Mass	kilogram	kg
Time	second	s
ElectricCurrent	ampere	A
Temperature	kelvin	K
AmountOfSubstance	mole	mol
LuminousIntensity	candela	cd
Currency	Euro	E

$$SI\_Value = ConversionFactorToSI * Value + ConversionOffsetToSI \quad (1)$$

The fields in the *UnitsOfMeasure* table are described in Table 5-27. The *UnitID* field is the primary key field with an Autoincrement (+) data type and acts as a unique identifier to reference each unit of measure. The *UnitName* field will hold a short text representation of the unit of measure (e.g. "m^3/s"). The *UnitDesc* field will hold a longer text description of the unit of measure. The *UnitCategory* field will allow units of measure to be grouped into categories (e.g. "Flow Rate") to enable users to more easily locate a required unit of measure. The *ConversionFactorToSI* field will hold values specifying the conversion factor to convert the unit of measure to SI units and would have a default value of "1.0". The *ConversionOffsetToSI* field will hold values specifying the conversion offset to convert the unit of measure to SI units and would have a default value of "0.0". The remaining fields represent the eight base dimensions shown in

Table 5-26 and store the power to which the SI base unit forming the unit of measure is raised, the default value for each of these fields is zero. For example, to represent the dimensions of cubic meters per second, the *Dim_Length* field would have a value of “3” and the *Dim_Time* field would have a value of “-1”. The dimensions of cubic meters per hour would be the same as for cubic meters per second but a conversion factor of “1/3600” to SI units would be specified. The *UnitsOfMeasure* table has been populated with the units of measure listed in Section 5.4. The advantages of the*UnitsOfMeasure* table are that it fully describes the units of measure, enables conversions between units of measure and allows for new units of measure to be easily added. However, for this system of units of measure to work it is important that all SPATSIM-HDSF databases use exactly the same units of measure table so that if data is moved between SPATSIM-HDSF project databases units of measure can simply be transferred. Users of SPATSIM-HDSF may not add or edit records in the *UnitsOfMeasure* table, if a new unit of measure is required by a user the developers of SPATSIM-HDSF will add it to the table which will be made available to all users.

Table 5-27 Description of the fields in the *UnitsOfMeasure* table

Field	Description
UnitID	A unique ID number associated with the unit of measure.
UnitName	A short name for the unit of measure.
UnitDesc	A description of the unit of measure.
UnitCategory	The category to which the unit of measure belongs.
ConversionFactorToSI	The factor to be used to convert a value with this unit of measure to the SI unit of measure.
ConversionOffsetToSI	The offset to be used to convert a value with this unit of measure to the SI unit of measure.
Dim_Length	The power of the length dimension of the unit of measure.
Dim_Mass	The power of the mass dimension of the unit of measure.
Dim_Time	The power of the time dimension of the unit of measure.
Dim_ElectricCurrent	The power of the electric current dimension of the unit of measure.
Dim_Temperature	The power of the temperature dimension of the unit of measure.
Dim_AmountOfSubstance	The power of the amount of substance dimension of the unit of measure.
Dim_LuminousIntensity	The power of the luminous intensity dimension of the unit of measure.
Dim_Currency	The power of the currency dimension of the unit of measure.

Table 5-28 Specifications for the *UnitsOfMeasure* table

Field	Type	Primary Key	Required	Maximum Value	Minimum Value	Default Value
UnitID	COUNTER	✓	✓			
UnitName	VARCHAR (20)		✓			
UnitDesc	VARCHAR (100)					
UnitCategory	VARCHAR (20)		✓			
ConversionFactorToSI	DOUBLE		✓			1.0
ConversionOffsetToS	DOUBLE		✓			0.0

I						
Dim_Length	SMALLINT		✓			0
Dim_Mass	SMALLINT		✓			0
Dim_Time	SMALLINT		✓			0
Dim_ElectricCurrent	SMALLINT		✓			0
Dim_Temperature	SMALLINT		✓			0
Dim_AmountOfSubstance	SMALLINT		✓			0
Dim_LuminousIntensity	SMALLINT		✓			0
Dim_Currency	SMALLINT		✓			0

Attribute Value Table: *TextData*

Table 5-29 Description of the fields in a *TextData* table (after Hughes, 2005; IWR, 2005)

Field	Description
RECID	A unique ID number associated with each Attribute data record.
TextValue	Text Attribute data.

Table 5-30 Specifications for the *TextData* table

Field	Type	Primary Key	Required	Maximum Value	Minimum Value	Default Value
RECID	COUNTER	✓	✓			
TextValue	VARCHAR (80)		✓			

Attribute Value Table: *IntegerData*

Table 5-31 Description of the fields in an *IntegerData* table (after Hughes, 2005; IWR, 2005)

Field	Description
RECID	A unique ID number associated with each Attribute data record.
IntValue	Integer Attribute value.

Table 5-32 Specifications for the *IntegerData* table

Field	Type	Primary Key	Required	Maximum Value	Minimum Value	Default Value
RECID	COUNTER	✓	✓			
IntValue	INTEGER		✓			

Attribute Value Table: *RealData*

Table 5-33 Description of the fields in a *RealData* table (after Hughes, 2005; IWR, 2005)

Field	Description
RECID	A unique ID number associated with each Attribute data record.
RealValue	Real Attribute value.

Table 5-34 Specifications for the *RealData* table

Field	Type	Primary Key	Required	Maximum Value	Minimum Value	Default Value
RECID	COUNTER	✓	✓			
RealValue	DOUBLE		✓			

Attribute Value Table: *TimeSeriesData*

Table 5-35 Description of the fields in a *TimeSeriesData* table (after Hughes, 2005; IWR, 2005)

Field	Description
RECID	A unique ID number associated with each Attribute data record.
GeogID	A text description of the data source location.
DataID	A text description of the data type (e.g. "Daily Rainfall").
DataObj	A data type code: 0 = fixed interval (data value only), 1 = variable interval (pairs of date/time and data value), 2 = variable interval (pairs of interval length and data value).
TimeUnits	The units of the time data: 1 = minutes, 2 = hours, 3 = days, 4 = months, 5 = years.
TimeInt	The time interval (when the data type code in the *Data Obj.* field is 0).
MDCode	The missing data code used in the time series data.
UnitID	A unique ID number associated with the unit of measure. References the *UnitID* field in the *UnitsOfMeasure* table.
AggType	The aggregation type of the time series data: 0 = should not be aggregated, 1= sum, 2 = average, 3 = maximum, 4 = minimum.
Scale	The value to be used to scale the data.
FlagKey	A unique ID number associated with the flag key. References the *FlagKey* field in the *tsflag* table.
StartDateTime	The start date and time of the time series.
EndDateTime	The end date and time of the time series.
NumRecords	The number of records in the time series.
TSData	The time series stored in a BLOB as a series of values for fixed interval data or stored as a series of time and value pairs.

Table 5-36 Specifications for the *TimeSeriesData* table

Field	Type	Primary Key	Required	Maximum Value	Minimum Value	Default Value
RECID	COUNTER	✓	✓			
GeogID	VARCHAR (80)					
DataID	VARCHAR (80)					
DataObj	SMALLINT		✓			
TimeUnits	SMALLINT		✓			
TimeInt	SMALLINT		✓			
MDCode	DOUBLE		✓			
UnitID	INTEGER		✓			
AggType	SMALLINT		✓			
Scale	DOUBLE		✓			
FlagKey	INTEGER		✓			
StartDateTime	DATETIME		✓			
EndDateTime	DATETIME		✓			
NumRecords	INTEGER		✓			
TSData	LONGBINARY		✓			

Time Series Flag Table: *tsflag*

Table 5-37 Description of the fields in a *tsflag* table

Field	Description
FlagKey	A unique ID number associated with each flag key.
Description	Text description of the flag key.
F1…F30	Flag.
FD1…FD30	Flag.

Table 5-38 Specifications for the *tsflag* table

Field	Type	Primary Key	Required	Maximum Value	Minimum Value	Default Value
FlagKey	COUNTER	✓	✓			
Description	VARCHAR (40)		✓			
F1	VARCHAR (10)		✓			
FD1	VARCHAR (40)		✓			
F2...F30	VARCHAR (10)					
FD2…FD30	VARCHAR (40)					

Attribute Value Table: *PictureData*

Table 5-39 Description of the fields in a *PictureData* table (after Hughes, 2005; IWR, 2005)

Field	Description
RECID	A unique ID number associated with each Attribute data record.
Title	A text title for the picture.
Xsize	The horizontal size of the picture in pixels.
Ysize	The vertical size of the picture in pixels.
RecDate	The date of creation or loading of the picture.
Type	A type code for the picture file: 0 = bmp, 1 = cgm, 2 = jpg, 3 = pcx, 4 = tif, 5 = gif, 6 = wmf, 7 = mpg, 8 = avi, 9 = mov
Picture	The picture stored as a BLOB.

Table 5-40 Specifications for the *PictureData* table

Field	Type	Primary Key	Required	Maximum Value	Minimum Value	Default Value
RECID	COUNTER	✓	✓			
Title	VARCHAR (80)					
Xsize	SMALLINT					
Ysize	SMALLINT					
RecDate	DATETIME					
Type	SMALLINT		✓			
Picture	LONGBINARY		✓			

Attribute Value Table: *ArrayData*

Table 5-41 Description of the fields in an *ArrayData* table (after Hughes, 2005; IWR, 2005)

Field	Description
RECID	A unique ID number associated with each Attribute data record.
Title	A text title for the array.
RecDate	The date of creation or loading of the array.
NumRows	The number of rows in the array.
NumColumns	The number of columns in the array.
Format	The filename of a text file (*.*txp*) specifying the structure of the array.
ArrayData	The values in the array stored as a BLOB, where each value is represented by a 4 byte real number.

Table 5-42 Specifications for the *ArrayData* table

Field	Type	Primary Key	Required	Maximum Value	Minimum Value	Default Value
RECID	COUNTER	✓	✓			
Title	VARCHAR (80)					
RecDate	DATETIME					
NumRows	SMALLINT					
NumColumns	SMALLINT					
Format	VARCHAR (80)		✓			
ArrayData	LONGBINARY		✓			

Attribute Value Table: *MemoData*

Table 5-43 Description of the fields in a *MemoData* table (after Hughes, 2005; IWR, 2005)

Field	Description
RECID	A unique ID number associated with each Attribute data record.
Title	A text title for the memo.
RecDate	The date of creation or loading of the memo.
MemoValue	Text data stored in a memo type field

Table 5-44 Specifications for the *MemoData* table

Field	Type	Primary Key	Required	Maximum Value	Minimum Value	Default Value
RECID	COUNTER	✓	✓			
Title	VARCHAR (80)					
RecDate	DATETIME					
MemoValue	LONGCHAR		✓			

Attribute Value Table: *LinkData*

Table 5-45 Description of the fields in a *LinkData* table (after Hughes, 2005; IWR, 2005)

Field	Description
RECID	A unique ID number associated with each Attribute data record.
Feature	The ID number of the Feature acting as the data source. References the *FeatureCode* field of the *data_dict1* table.
Attribute	The ID number of the Attribute acting as the data source. References the *AttributeCode* field of the *data_dict3* table.
Type	The data type of the data source Attribute as specified in the *data_dict3* table.
ObjectRecord	The ID number of the source Object that will be used to locate the data. References the *IDField* of the *ShapefileDbfTable* or *NonSpatialFeatureTable* table for the relevant Feature.

Table 5-46 Specifications for the *LinkData* table

Field	Type	Primary Key	Required	Maximum Value	Minimum Value	Default Value
RECID	COUNTER	✓	✓			
Feature	INTEGER		✓			
Attribute	INTEGER		✓			
Type	SMALLINT		✓			
ObjectRecord	INTEGER		✓			

Internal GIS Feature Theme Table: FeatureTheme

Table 5-47 Description of the fields in a *FeatureTheme* table

Field	Description
ID	String containing a GUID used to identify the Feature theme.
FeatureCode	A unique ID number associated with a single Feature. References the *FeatureCode* field in the *data_dict1* table.
ThemeName	The name of the Feature theme for display and selection purposes.
ThemeData	A string storing a XML serialized theme definition object used to store information about the Feature theme.
IsDefault	A Boolean value specifying whether this Feature theme is the default theme for the Feature to which it belongs.

Table 5-48 Specifications for the *FeatureTheme* table

Field	Type	Primary Key	Required	Maximum Value	Minimum Value	Default Value
ID	VARCHAR(40)	✓	✓			
FeatureCode	INTEGER		✓			
ThemeName	VARCHAR(255)		✓			
ThemeData	LONGCHAR		✓			
IsDefault	BOOLEAN		✓			

External GIS Base Data Table: ETBaseData

Table 5-49 Description of the fields in a *ETBaseData* table

Field	Description
ETBaseDataID	A unique ID number associated with a base dataset.
DataSetSource	The path and filename of a base dataset.
DataSetName	The name of the base dataset for display and selection purposes.
FeatureType	An integer number identifying the type of Feature: 1 = Spatial, 2 = Image, 3 = Non-spatial, 4 = GRID.

Table 5-50 Specifications for the *ETBaseData* table

Field	Type	Primary Key	Required	Maximum Value	Minimum Value	Default Value
ETBaseDataID	COUNTER	✓	✓			
DataSetSource	VARCHAR(255)		✓			
DataSetName	VARCHAR(50)		✓			
FeatureType	SMALLINT		✓			

External GIS Automatic Calculation Table: ETAutoCalc

Table 5-51 Description of the fields in a *ETAutoCalc* table

Field	Description
ETAutoCalcID	A unique ID number assigned to each record.
AttributeCode	A unique ID number associated with the Attribute. References the *AttributeCode* field in the *data_dict3* table.
ETBaseDataID	A unique ID number associated with a base dataset. References the *ETBaseDataID* field in the *ETBaseData* table.

Table 5-52 Specifications for the *ETAutoCalc* table

Field	Type	Primary Key	Required	Maximum Value	Minimum Value	Default Value
ETAutoCalcID	COUNTER	✓	✓			
AttributeCode	INTEGER		✓			
ETBaseDataID	INTEGER		✓			

5.4 Units of Measure Included in the *UnitsOfMeasure* Table

Each unit of measure has been assigned to a category. The units of measure and their properties are shown in the tables below. The conversion factors and offsets to SI units were based on SABS (1973).

Table 5-53 Units of measure for the Area category

UnitName	UnitDesc	UnitCategory	ConversionFactorToSI	ConversionOffsetToSI	Dim_Length	Dim_Mass	Dim_Time	Dim_ElectricCurrent	Dim_Temperature	Dim_AmountOfSubstance	Dim_LuminousIntensity	Dim_Currency
mm^2	square millimetre	Area	1.0 E-6	0.0	2	0	0	0	0	0	0	0
cm^2	square centimetre	Area	1.0 E-4	0.0	2	0	0	0	0	0	0	0
m^2	square metre	Area	1.0	0.0	2	0	0	0	0	0	0	0
ha	hectare	Area	1.0 E+4	0.0	2	0	0	0	0	0	0	0
km^2	square kilometre	Area	1.0 E+6	0.0	2	0	0	0	0	0	0	0
ft^2	square foot	Area	9.290304 E-2	0.0	2	0	0	0	0	0	0	0
acre	acre	Area	4.04686 E+3	0.0	2	0	0	0	0	0	0	0
mi^2	square mile	Area	2.589988 E+6	0.0	2	0	0	0	0	0	0	0

Table 5-54 Units of measure for the Concentration category

UnitName	UnitDesc	UnitCategory	ConversionFactorToSI	ConversionOffsetToSI	Dim_Length	Dim_Mass	Dim_Time	Dim_ElectricCurrent	Dim_Temperature	Dim_AmountOfSubstance	Dim_LuminousIntensity	Dim_Currency
mg/l	milligram per litre	Concentration	1.0 E-3	0.0	-3	1	0	0	0	0	0	0
g/l	gram per litre	Concentration	1.0	0.0	-3	1	0	0	0	0	0	0
kg/m^3	kilogram per cubic metre	Concentration	1.0	0.0	-3	1	0	0	0	0	0	0
t/m^3	tonne per cubic metre	Concentration	1.0 E+3	0.0	-3	1	0	0	0	0	0	0
cwt/ft^3	hundredweight per cubic foot	Concentration	1.794068 E+3	0.0	-3	1	0	0	0	0	0	0
cwt/gall	hundred weight per gallon (UK)	Concentration	1.117496 E+4	0.0	-3	1	0	0	0	0	0	0
ton/ft^3	ton (long) per cubic foot	Concentration	3.588136 E+4	0.0	-3	1	0	0	0	0	0	0
ton/gall	ton (long) per gallon	Concentration	2.234991 E+5	0.0	-3	1	0	0	0	0	0	0

Table 5-55 Units of measure for the Cost category

UnitName	UnitDesc	UnitCategory	ConversionFactorToSI	ConversionOffsetToSI	Dim_Length	Dim_Mass	Dim_Time	Dim_ElectricCurrent	Dim_Temperature	Dim_AmountOfSubstance	Dim_LuminousIntensity	Dim_Currency
R	Rand	Cost	1.0	0.0	0	0	0	0	0	0	0	1
R/ha	Rand per hectare	Cost	1.0 E-4	0.0	-2	0	0	0	0	0	0	1
R/m^3	Rand per cubic metre	Cost	1.0	0.0	-3	0	0	0	0	0	0	1
R/kl	Rand per kilo litre	Cost	1.0	0.0	-3	0	0	0	0	0	0	1
R/kg	Rand per kg	Cost	1.0	0.0	0	-1	0	0	0	0	0	1
R/t	Rand per ton	Cost	1.0 E-3	0.0	0	-1	0	0	0	0	0	1
R/kW h	Rand per kilo watt hour	Cost	2.777778 E-7	0.0	-2	-1	2	0	0	0	0	1

Table 5-56 Units of measure for the Dimensionless category

UnitName	UnitDesc	UnitCategory	ConversionFactorToSI	ConversionOffsetToSI	Dim_Length	Dim_Mass	Dim_Time	Dim_ElectricCurrent	Dim_Temperature	Dim_AmountOfSubstanc	Dim_LuminousIntensity	Dim_Currency
?	Unknown	Dimensionless	0.0	0.0	0	0	0	0	0	0	0	0
-	Dimensionless	Dimensionless	0.0	0.0	0	0	0	0	0	0	0	0
Fraction	Fraction	Dimensionless	1.0	0.0	0	0	0	0	0	0	0	0
Ratio	Ratio	Dimensionless	1.0	0.0	0	0	0	0	0	0	0	0
%	percent	Dimensionless	1.0 E -2	0.0	0	0	0	0	0	0	0	0
pH	pH	Dimensionless	1.0	0.0	0	0	0	0	0	0	0	0
Index	Index	Dimensionless	1.0	0.0	0	0	0	0	0	0	0	0

Table 5-57 Units of measure for the Electrical category

UnitName	UnitDesc	UnitCategory	ConversionFactorToSI	ConversionOffsetToSI	Dim_Length	Dim_Mass	Dim_Time	Dim_ElectricCurrent	Dim_Temperature	Dim_AmountOfSubstanc	Dim_LuminousIntensity	Dim_Currency
A	ampere	Electrical	1.0	0.0	0	0	0	1	0	0	0	0
V	volt	Electrical	1.0	0.0	2	1	-3	-1	0	0	0	0
Ω	ohm	Electrical	1.0	0.0	2	1	-3	-2	0	0	0	0
C	coulomb	Electrical	1.0	0.0	0	0	1	1	0	0	0	0
F	farad	Electrical	1.0	0.0	-2	-1	4	2	0	0	0	0
S	siemens	Electrical	1.0	0.0	-2	-1	3	2	0	0	0	0
MS/m	mega siemens per metre	Electrical	1.0	0.0	-3	-1	3	2	0	0	0	0

Table 5-58 Units of measure for the Energy category

UnitName	UnitDesc	UnitCategory	ConversionFactorToSI	ConversionOffsetToSI	Dim_Length	Dim_Mass	Dim_Time	Dim_ElectricCurrent	Dim_Temperature	Dim_AmountOfSubstanc	Dim_LuminousIntensity	Dim_Currency
J	joule	Energy	1.0	0.0	2	1	-2	0	0	0	0	0
W	watt	Energy	1.0	0.0	2	1	-3	0	0	0	0	0
kW	kilo watt	Energy	1.0 E+3	0.0	2	1	-3	0	0	0	0	0
MW	mega watt	Energy	1.0 E+6	0.0	2	1	-3	0	0	0	0	0
kW h	kilowatt hour	Energy	3.6 E+6	0.0	2	1	-2	0	0	0	0	0
MJ/cm^2	mega joules per square centimetre	Energy	1.0 E+10	0.0	0	1	-2	0	0	0	0	0
MJ/m^2	mega joules per square metre	Energy	1.0 E+6	0.0	0	1	-2	0	0	0	0	0
MJ/cm^2/d	mega joules per square centimetre per day	Energy	1.157407 E+5	0.0	0	1	-2	0	0	0	0	0
MJ/m^2/d	mega joules per square metre per day	Energy	1.157407 E+1	0.0	0	1	-2	0	0	0	0	0
J/kg	joule per kilogram	Energy	1.0	0.0	2	0	-2	0	0	0	0	0
J/kg/°C	joules per kilogram per degree Celsius	Energy	1.0	0.0	2	0	-2	0	-1	0	0	0

Table 5-59 Units of measure for the Flux category

UnitName	UnitDesc	UnitCategory	ConversionFactorToSI	ConversionOffsetToSI	Dim_Length	Dim_Mass	Dim_Time	Dim_ElectricCurrent	Dim_Temperature	Dim_AmountOfSubstanc	Dim_LuminousIntensity	Dim_Currency
mm/h	millimetre per hour	Flux	2.777778 E-7	0.0	1	0	-1	0	0	0	0	0
mm/d	millimetre per day	Flux	1.157407 E-8	0.0	1	0	-1	0	0	0	0	0
mm/month	millimetre per month	Flux	0.0	0.0	1	0	-1	0	0	0	0	0
mm/annum	millimetre per annum	Flux	0.0	0.0	1	0	-1	0	0	0	0	0
m/s	metre per second	Flux	1.0	0.0	1	0	-1	0	0	0	0	0
m/h	metre per hour	Flux	2.777778 E-4	0.0	1	0	-1	0	0	0	0	0
m/d	metre per day	Flux	1.157407 E-5	0.0	1	0	-1	0	0	0	0	0
km/h	kilometres per hour	Flux	2.777778 E-1	0.0	1	0	-1	0	0	0	0	0
km/d	kilometres per day	Flux	1.157407 E-2	0.0	1	0	-1	0	0	0	0	0
ft/s	foot per second	Flux	3.048 E-1	0.0	1	0	-1	0	0	0	0	0
mi/h	miles per hour	Flux	4.4704 E-1	0.0	1	0	-1	0	0	0	0	0
mi/d	miles per day	Flux	1.862667 E-2	0.0	1	0	-1	0	0	0	0	0

Table 5-60 Units of measure for the Length category

UnitName	UnitDesc	UnitCategory	ConversionFactorToSI	ConversionOffsetToSI	Dim_Length	Dim_Mass	Dim_Time	Dim_ElectricCurrent	Dim_Temperature	Dim_AmountOfSubstance	Dim_LuminousIntensity	Dim_Currency
µm	micrometre	Length	1.0 E-6	0.0	1	0	0	0	0	0	0	0
mm	millimetre	Length	1.0 E-3	0.0	1	0	0	0	0	0	0	0
cm	centimetre	Length	1.0 E-2	0.0	1	0	0	0	0	0	0	0
m	metre	Length	1.0	0.0	1	0	0	0	0	0	0	0
km	kilometre	Length	1.0 E+3	0.0	1	0	0	0	0	0	0	0
mm/mm	millimetre per millimetre	Length	1.0	0.0	0	0	0	0	0	0	0	0
m/m	metre per metre	Length	1.0	0.0	0	0	0	0	0	0	0	0
in	inch	Length	2.54 E-2	0.0	1	0	0	0	0	0	0	0
ft	foot	Length	3.048 E-1	0.0	1	0	0	0	0	0	0	0
yd	yard	Length	9.144 E-1	0.0	1	0	0	0	0	0	0	0
mi	mile	Length	1.609344 E+3	0.0	1	0	0	0	0	0	0	0

Table 5-61 Units of measure for the Mass category

UnitName	UnitDesc	UnitCategory	ConversionFactorToSI	ConversionOffsetToSI	Dim_Length	Dim_Mass	Dim_Time	Dim_ElectricCurrent	Dim_Temperature	Dim_AmountOfSubstance	Dim_LuminousIntensity	Dim_Currency
mg	milligram	Mass	1.0 E-6	0.0	0	1	0	0	0	0	0	0
g	gram	Mass	1.0 E-3	0.0	0	1	0	0	0	0	0	0
kg	kilogram	Mass	1.0	0.0	0	1	0	0	0	0	0	0
t	tonne	Mass	1.0 E+3	0.0	0	1	0	0	0	0	0	0
cwt (UK)	hundredweight (UK)	Mass	5.080235 E+1	0.0	0	1	0	0	0	0	0	0
ton (long)	ton (long)	Mass	1.016047 E+3	0.0	0	1	0	0	0	0	0	0
g/g	gram per gram	Mass	1.0	0.0	0	0	0	0	0	0	0	0

Table 5-62 Units of measure for the Mechanical category

UnitName	UnitDesc	UnitCategory	ConversionFactorToSI	ConversionOffsetToSI	Dim_Length	Dim_Mass	Dim_Time	Dim_ElectricCurrent	Dim_Temperature	Dim_AmountOfSubstanc	Dim_LuminousIntensity	Dim_Currency
N	newton	Mechanical	1.0	0.0	1	1	-2	0	0	0	0	0
Nm	newton metre	Mechanical	1.0	0.0	2	1	-2	0	0	0	0	0
N/m^2	newton per square metre	Mechanical	1.0	0.0	-1	1	-2	0	0	0	0	0
m/s^2	metres per second squared	Mechanical	1.0	0.0	1	0	-2	0	0	0	0	0

Table 5-63 Units of measure for the Plane Angle category

UnitName	UnitDesc	UnitCategory	ConversionFactorToSI	ConversionOffsetToSI	Dim_Length	Dim_Mass	Dim_Time	Dim_ElectricCurrent	Dim_Temperature	Dim_AmountOfSubstance	Dim_LuminousIntensity	Dim_Currency
rad	radian	Plane Angle	1.0	0.0	0	0	0	0	0	0	0	0
°	degree	Plane Angle	1.745329 E-2	0.0	0	0	0	0	0	0	0	0
‘	minute	Plane Angle	2.908882 E-4	0.0	0	0	0	0	0	0	0	0
“	second	Plane Angle	4.848137 E-6	0.0	0	0	0	0	0	0	0	0

Table 5-64 Units of measure for the Pressure category

UnitName	UnitDesc	UnitCategory	ConversionFactorToSI	ConversionOffsetToSI	Dim_Length	Dim_Mass	Dim_Time	Dim_ElectricCurrent	Dim_Temperature	Dim_AmountOfSubstance	Dim_LuminousIntensity	Dim_Currency
Pa	pascal	Pressure	1.0	0.0	-1	1	-2	0	0	0	0	0
kPa	kilopascal	Pressure	1.0 E +3	0.0	-1	1	-2	0	0	0	0	0
bar	bar	Pressure	1.0 E +5	0.0	-1	1	-2	0	0	0	0	0
Pa/°C	pascal per degree Celsius	Pressure	1.0	0.0	-1	1	-2	0	-1	0	0	0

Table 5-65 Units of measure for the Production category

UnitName	UnitDesc	UnitCategory	ConversionFactorToSI	ConversionOffsetToSI	Dim_Length	Dim_Mass	Dim_Time	Dim_ElectricCurrent	Dim_Temperature	Dim_AmountOfSubstanc	Dim_LuminousIntensity	Dim_Currency
g/m^2	grams per square metre	Production	1.0 E-3	0.0	-2	1	0	0	0	0	0	0
g/ha	grams per hectare	Production	1.0 E-7	0.0	-2	1	0	0	0	0	0	0
Mg/ha	mega grams per hectare	Production	1.0 E-1	0.0	-2	1	0	0	0	0	0	0
kg/ha	kilograms per hectare	Production	1.0 E-4	0.0	-2	1	0	0	0	0	0	0
t/ha	tonnes per hectare	Production	1.0 E-1	0.0	-2	1	0	0	0	0	0	0
ton/acre	ton (long) per acre	Production	2.51071 E-1	0.0	-2	1	0	0	0	0	0	0
m^3/ha	cubic metres per hectare	Production	1.0 E-4	0.0	1	0	0	0	0	0	0	0

Table 5-66 Units of measure for the Rate category

UnitName	UnitDesc	UnitCategory	ConversionFactorToSI	ConversionOffsetToSI	Dim_Length	Dim_Mass	Dim_Time	Dim_ElectricCurrent	Dim_Temperature	Dim_AmountOfSubstanc	Dim_LuminousIntensity	Dim_Currency
ml/d	millilitre per day	Rate	1.157407 E-11	0.0	3	0	-1	0	0	0	0	0
l/s	litre per second	Rate	1.0 E-3	0.0	3	0	-1	0	0	0	0	0
m^3/s	cubic metre per second	Rate	1.0	0.0	3	0	-1	0	0	0	0	0
m^3/h	cubic metre per hour	Rate	2.777778 E-4	0.0	3	0	-1	0	0	0	0	0
m^3/d	cubic metre per day	Rate	1.157407 E-5	0.0	3	0	-1	0	0	0	0	0
m^3/month	cubic metre per month	Rate	0.0	0.0	3	0	-1	0	0	0	0	0
m^3/annum	cubic metre per annum	Rate	0.0	0.0	3	0	-1	0	0	0	0	0
Mm^3/d	million cubic metres per day	Rate	1.157407 E+1	0.0	3	0	-1	0	0	0	0	0
Mm^3/month	million cubic metres per month	Rate	0.0	0.0	3	0	-1	0	0	0	0	0
Mm^3/annum	million cubic metres per annum	Rate	0.0	0.0	3	0	-1	0	0	0	0	0
ft^3/s	cubic feet per second	Rate	2.831685 E-2	0.0	3	0	-1	0	0	0	0	0
gall/h	gallon (UK) per hour	Rate	1.262803 E-6	0.0	3	0	-1	0	0	0	0	0
gall/d	gallon (UK) per day	Rate	5.261678 E-8	0.0	3	0	-1	0	0	0	0	0

Table 5-67 Units of measure for the Temperature category

UnitName	UnitDesc	UnitCategory	ConversionFactorToSI	ConversionOffsetToSI	Dim_Length	Dim_Mass	Dim_Time	Dim_ElectricCurrent	Dim_Temperature	Dim_AmountOfSubstance	Dim_LuminousIntensity	Dim_Currency
K	Kelvin	Temperature	1.0	0.0	0	0	0	0	1	0	0	0
°C	degrees Celsius	Temperature	1.0	2.7315 E+2	0	0	0	0	1	0	0	0
° F	degrees Fahrenheit	Temperature	5.5555556 E-1	2.5537222 E+2	0	0	0	0	1	0	0	0
°C/ 1000 m	degrees Celsius per 1000 metres	Temperature	1.0 E-3	2.7315 E+2	-1	0	0	0	1	0	0	0
°C days	growing degree days (°C)	Temperature	8.64 E+4	2.7315 E+2	0	0	1	0	1	0	0	0

Table 5-68 Units of measure for the Time category

UnitName	UnitDesc	UnitCategory	ConversionFactorToSI	ConversionOffsetToSI	Dim_Length	Dim_Mass	Dim_Time	Dim_ElectricCurrent	Dim_Temperature	Dim_AmountOfSubstance	Dim_LuminousIntensity	Dim_Currency
s	second	Time	1.0	0.0	0	0	1	0	0	0	0	0
min	minute	Time	6.0 E+1	0.0	0	0	1	0	0	0	0	0
h	hour	Time	3.6 E+3	0.0	0	0	1	0	0	0	0	0
d	day	Time	8.64 E+4	0.0	0	0	1	0	0	0	0	0
week	week	Time	6.048 E+5	0.0	0	0	1	0	0	0	0	0
month	month	Time	0.0	0.0	0	0	1	0	0	0	0	0
year	year	Time	0.0	0.0	0	0	1	0	0	0	0	0

Table 5-69 Units of measure for the Volume category

UnitName	UnitDesc	UnitCategory	ConversionFactorToSI	ConversionOffsetToSI	Dim_Length	Dim_Mass	Dim_Time	Dim_ElectricCurrent	Dim_Temperature	Dim_AmountOfSubstanc	Dim_LuminousIntensity	Dim_Currency
ml	millilitre	Volume	1.0 E-6	0.0	3	0	0	0	0	0	0	0
l	litre	Volume	1.0 E-3	0.0	3	0	0	0	0	0	0	0
kl	kilolitre	Volume	1.0	0.0	3	0	0	0	0	0	0	0
Ml	mega litre	Volume	1.0 E+3	0.0	3	0	0	0	0	0	0	0
dm^3	decimetre cubed	Volume	1.0 E-3	0.0	3	0	0	0	0	0	0	0
m^3	cubic metre	Volume	1.0	0.0	3	0	0	0	0	0	0	0
Mm^3	million cubic metres	Volume	1.0 E+6	0.0	3	0	0	0	0	0	0	0
ft^3	cubic foot	Volume	2.831685 E-2	0.0	3	0	0	0	0	0	0	0
acre ft	acre foot	Volume	1.233482 E+3	0.0	3	0	0	0	0	0	0	0
gall	gallon (UK)	Volume	4.54609 E-3	0.0	3	0	0	0	0	0	0	0
Mill.gall	million gallons (UK)	Volume	4.54609 E+3	0.0	3	0	0	0	0	0	0	0
m^3/m^3	cubic metre per cubic metre	Volume	1.0	0.0	0	0	0	0	0	0	0	0

6. LIST OF ACRONYMS

AAHMS	*ACRU* Agrohydrological Modelling System
AAMG	Amalgamation of Agro-Hydrological Modelling Groups
AQCD	*ACRU* Quaternary Catchments Database
BDE	Borland Database Engine
BEEH	School of Bioresources Engineering and Environmental Hydrology
BLOB	Binary Large Object
CEH	Centre for Ecology and Hydrology
CMA	Catchment Management Agencies
COM	Component Object Model
CRCCH	Cooperative Research Centre for Catchment Hydrology
CSV	Comma Separated Value
DLL	Dynamic Link Library
DWAF	Department of Water Affairs and Forestry
ESRI	Environmental Software Research Institute
FWACS	Fractional Water Allocations and Capacity Sharing
GIS	Geographic Information System
GUI	Graphical User Interface
HDSF	Hydrological Decision Support Framework
HTML	Hypertext Markup Language
IWMI	International Water Management Institute
IWR	Institute for Water Research
IWRM	Integrated Water Resources Management
JDBC	Java DataBase Connectivity
JNI	Java Native Interface
MAP	Mean Annual Precipitation
NWA	National Water Act of South Africa, Act 36 of 1998
RDBMS	Relational Database Management System
SQL	Structured Query Language
TMDL	Total Maximum Daily Load
UKZN	University of KwaZulu-Natal
UML	Universal Modelling Language
USA	United States of America
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VCL	Visual Component Library
WRC	Water Research Commission
WRYM	Water Resources Yield Model
XML	Extensible Markup Language

7. SUPPORT CONTACT DETAILS

THE INSTITUTE FOR WATER RESEARCH (IWR)

Address	:	Institute for Water Research Rhodes University PO Box 94, Grahamstown, 6140, South Africa
Telephone	:	+27 (0)46 6224014
Website	:	http://www.ru.ac.za/static/institutes/iwr/?request=iwr

School of Bioresources Engineering & Environmental Hydrology (BEEH)

Address	:	School of Bioresources Engineering & Environmental Hydrology University of KwaZulu-Natal Private Bag X01 Scottsville, 3209 Pietermaritzburg South Africa
Phone	:	+27 (0)33 260 5490
Fax	:	+27 (0)33 260 5818
Website	:	http://beeh.ukzn.ac.za/Homepage.aspx
Email	:	beeh@ukzn.ac.za

For support on the following aspects of SPATSIM-HDSF please contact the organisation indicated in Table 7-1 below.

Table 7-1 SPATSIM-HDSF support contacts listing.

1.	Installation	IWR, BEEH
2.	General support	IWR, BEEH
3.	Internal GIS Tools	BEEH
4.	T/S Analysis Tools	BEEH
5.	TSGraph Time Series Analysis Tools	IWR
6.	External GIS Tools	BEEH
7.	T/S Summary Procedure	IWR
8.	Drought Indices Procedure	IWR
9.	Sub Quat MAR Procedure	IWR
10.	*ACRU* Model support	BEEH
11.	Desktop Parameter Calibration Model	IWR
12.	Desktop Reserve Model	IWR
13.	Flow-Stressor Response Model	IWR
14.	Reserve Licensing Model linked to the Desktop Model	IWR
15.	Real Time Reserve Management Model	IWR
16.	Satellite Daily Rainfall Capture Process	IWR
17.	The Ground Water Version 3 Pitman Monthly Model	IWR
18.	Pitman Model Parameter Exploration	IWR
19.	The Ground Water Version 3 Uncertainty Pitman Monthly Model	IWR
20.	Developer Support	IWR, BEEH

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APPENDIX B

SPATSIM-HDSF: External GIS Tools

EXTERNAL GIS TOOLS FOR THE HYDROLOGICAL DECISION SUPPORT FRAMEWORK (HDSF)

User Manual

KB Meier, C Freese and DJ Clark

May 2008

Appendix B

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1. INTRODUCTION

GISs have become invaluable in hydrological modelling and GIS tools are an important component of the HDSF. The internal GIS tools in SPATSIM are suitable for visualisation of spatial data and simple editing of geographical data in a SPATSIM project. The functionality of the internal GIS tools is essentially limited to spatial feature queries and display. Much of the limitation on the internal GIS tools with regards functionality, in particular to raster queries, is attributed to the platform through which the internal GIS tools have been designed, namely MapObjects. MapObjects provides coded object classes which can be used in the development of computer programs to display and query feature classes. A comprehensive GIS package, such as ArcGIS, has the extended ability to analyse and query spatial feature and raster classes using methods which are not available in MapObjects. Using functionality which is available in a package such as ArcGIS can be extremely useful in setting up and inputting data to a hydrological database. For this reason it was decided to compile a set of external GIS tools which could be used together with ArcGIS for analysing hydrological datasets such that summary information pertaining to catchments could be automatically input to the HDSF database. The external GIS tools have been developed as an extension to the ArcGIS desktop software using the Visual Basic .Net (Version 2.0) programming language.

The "External GIS" tools is a set of functions built using ArcObjects and presented in ArcGIS as an extension. The extension has functionality to:

- Load Spatsim Data which is referenced in the Spatsim Database, into ArcGIS. After loading Spatsim spatial data to ArcGIS the data can be used for advance query or simply for display. ArcGIS has properties for creating advanced legends and can allow the setup of a layout view for printing data.

- Undertake Grid analysis of raster datasets containing hydrological variable or parameter information. The grid analysis functions available in the Spatial Analyst component of ArcGIS are used to analyse raster data overlaid on catchment boundaries and to then output summary information directly to the Spatsim Database. An example of this would be the analysis of gridded apan evaporation for January over each catchment so that the average value could be entered into the database.

- Undertake spatial queries of polygon on polygon coverages to allow the attributes of one coverage to be summarised based on another. An example of this would be the analysis of a soils coverage against a catchment coverage so as to calculate the average soil depth in the topsoil for each catchment of the database.

A guide to the installation of the external GIS tools is provided in section 1, and the operation of these tools is described in section 2.

2. INSTALLATION

Create a folder on your hard drive with an applicable name and into it copy the file named *ExternalGISTools.zip*. Then unzip this *ExternalGISTools.zip* file. The unzipped files are as follows:

- *HDSF.dll*
- *HDSF.pdb*
- *HDSF.xml*
- *Register.bat*
- *SDSGenericClass.dll*
- *SDSGenericClass.pdb*
- *SDSGenericClass.xml*
- *SDSSpatialAnalystClass.dll*
- *SDSSpatialAnalystClass.pdb*
- *SDSSpatialAnalystClass.xml*

At this point it is critical to ensure that Microsoft .NET Framework (version 2 or later) is installed on your PC. This application can be downloaded from the Microsoft website (www.microsoft.com).

Once you have ensured that you have the correct version of ArcGIS and the .NET Framework is installed the software must be registered by simply running the *Register.bat* batch file. A command prompt window (like in the image below) should pop up with a diagnostic message to confirm that the registration is successful.

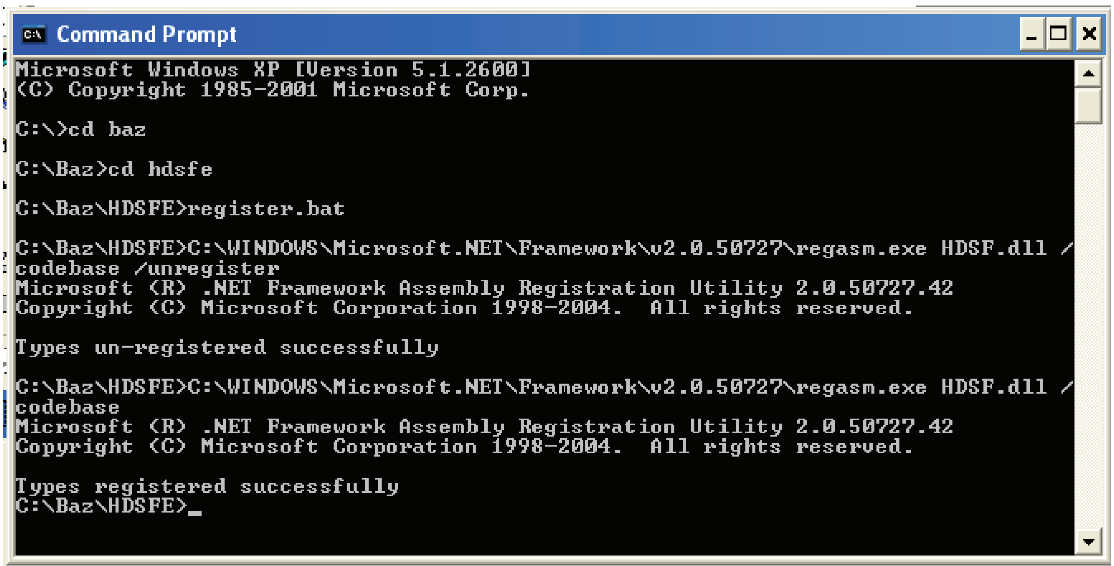

Figure 1: Successful registration of software using *Register.bat* batch file.

Once the Registration is complete ArcMap can be opened. The external GIS tools are activated as an extension. Under the *Tools* menu bar click on *Extensions* and click the box next to *ArcGIS HDSF Extension* so a tick appears in it.

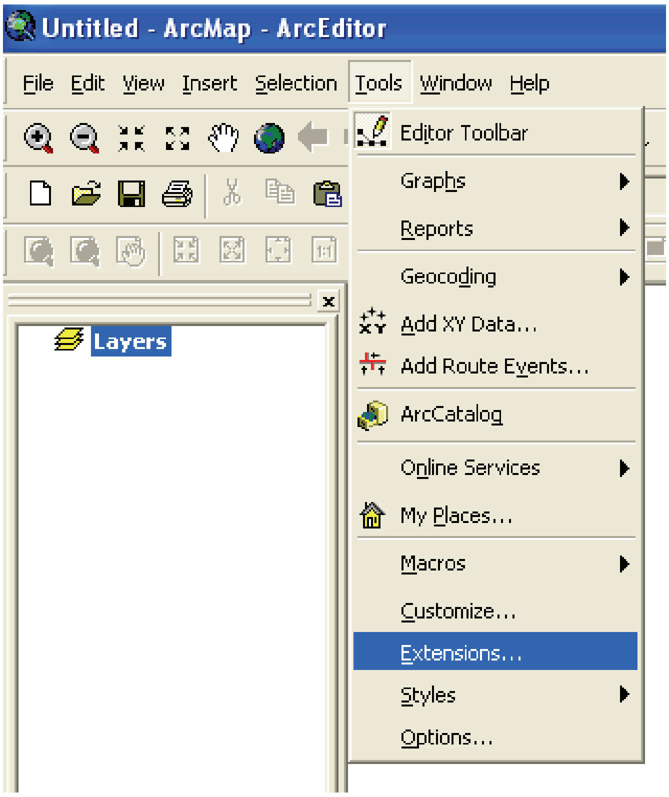

Figure 2: Path to extensions menu

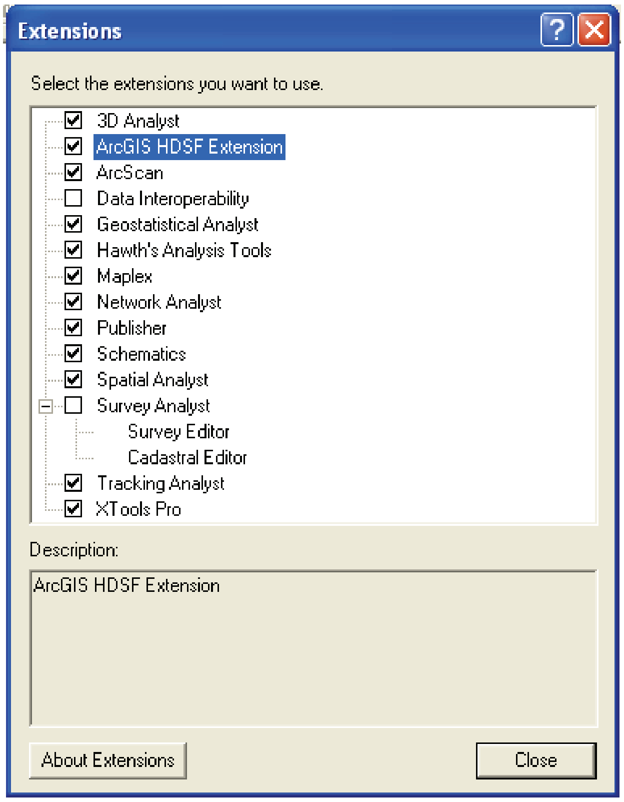

Figure 3: ArcGIS HDSF Extension.

Once the *ArcGIS HDSF Extension* has been activated under the extensions menu the HDSF toolbar needs to be made visible. This is done under the *View* menubar, click on *Toolbars* and click on HDSF so a tick appears next to it. The path to make the HDSF toolbar visible is shown in the screenshot below.

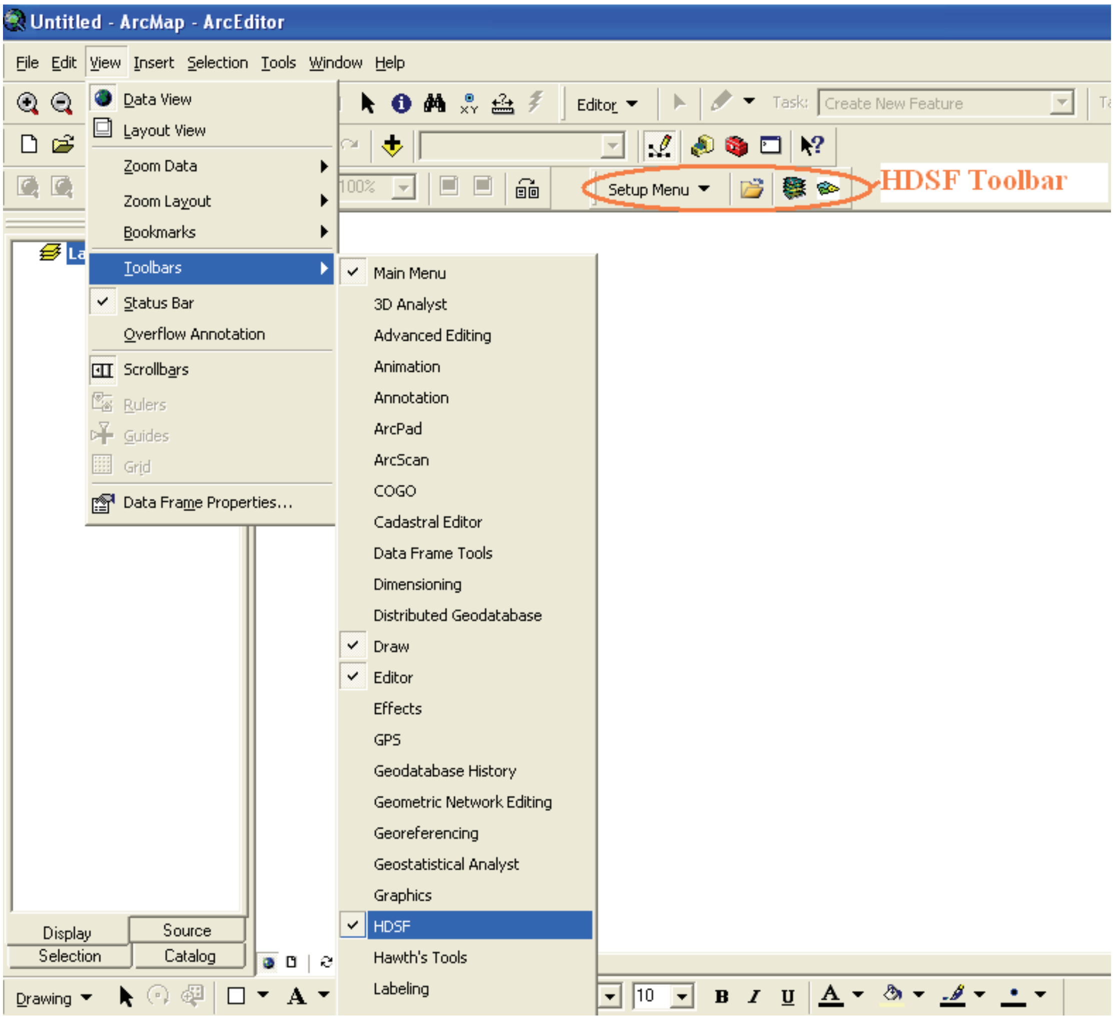

Figure 4: Path to make HDSF toolbar visible (Toolbar integrated into menu bar)

The HDSF toolbar can either be integrated into the menu bar (as in Figure 4 above) or it can be viewed as a floating toolbar as in Figure 5 below.

Figure 5: HDSF floating toolbar

3. OPERATION OF TOOLS

Once the installation and registration have been carried out successfully the projects directory needs to be set. This is to specify the location of the database to which all extracted information will be stored and referenced in various tables. The tool bar acts as a connection to the database, specifically through the *select project dir* option that appears under *Setup Menu* as in the screenshot below.

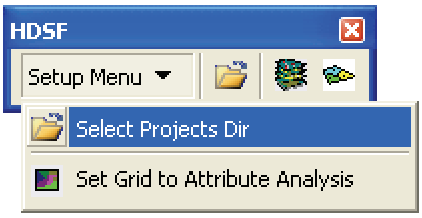

Figure 6: HDSF toolbar.

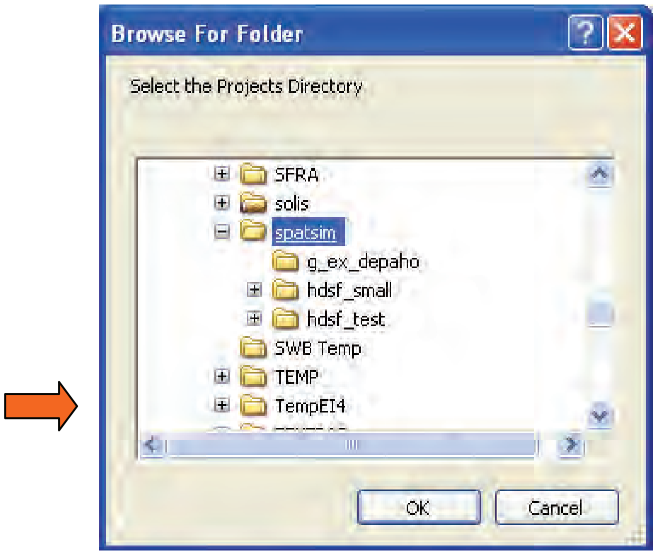

Figure 7: Setting the projects folder.

Now that the projects directory has been set you can now load a HDSF project by selecting the *Load HDSF Project* button

Figure 8: The *Load HDSF Project* button.

This allows you to load projects that already include grid and polygon coverage's from which data extractions can be carried out.

The project directory must be set, and the project must be loaded before any analysis can be performed!

3.1 Grid Analysis

Grid analysis carries out an extraction of data from a grid coverage based on a delineation of a landscape that has been classified in terms of a continuous fields view such as altitude, temperature, rainfall etc. Within the HDSF external GIS tools the grid coverage's and relating attributes are set out in the *Set Grid to Attribute Analysis.*

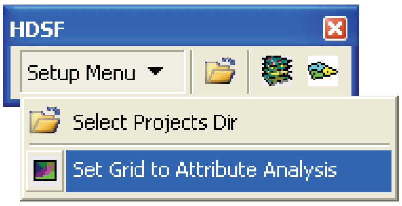

Figure 9: Setting the grid attributes to be analysed.

Within this menu the 'terms' of the extraction are assembled according to your preferences. For instance the example in Figure 9 below, in the *feature* field one would enter the coverage that defines the manner in which the landscape has been divided, in this example the landscape has been divided on a quaternary catchments scale (the fourth level division of South Africa's primary catchments such as the Umgeni catchment and the Thukela catchment)

The *Attribute* field which appears directly below the *Feature* field is used to define which attribute will be extracted and averaged over the *Feature* field

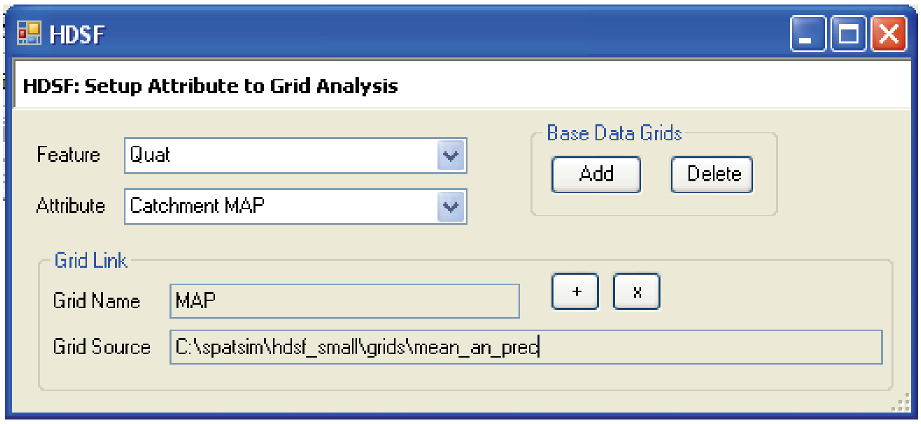

Figure 10: Setting up coverage attributed to be analysed

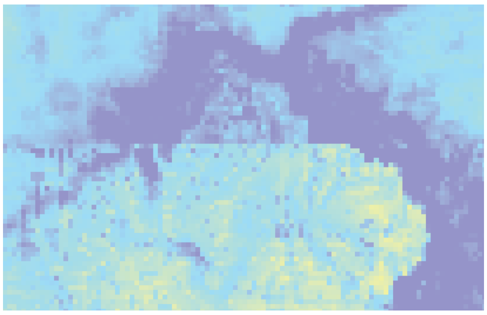

Figure 11: MAP grid coverage (attribute)

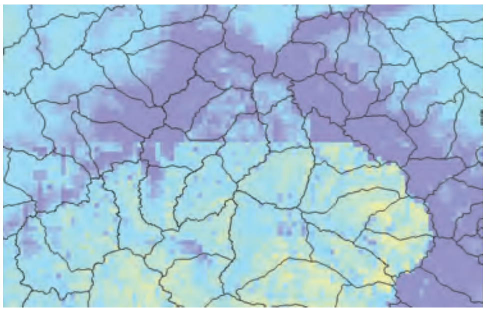

Figure 12: MAP grid with quaternary coverage overlayed (attribute & feature)

This will result in an average value for mean annual precipitation, or MAP, being extracted for each quaternary (unit of division of the landscape) and placed and referenced in the spatsim database.

The *Base Data Grid* box allows users to add new grid coverage's to be analysed, or delete existing attributes for a specific feature. To delete attributes, click on *Delete* in the *Base Data Grids* box and select the attribute you wish to terminate from the pop-up menu.

New grids are added by clicking on the *Add* button which opens the *formGetGrid* window. This window contains two input fields; *Grid Name* and *Grid Path*. The *Grid Name* field is a user defined name for the input grid, and the *Grid Path* specifies the path to where the grid is stored.

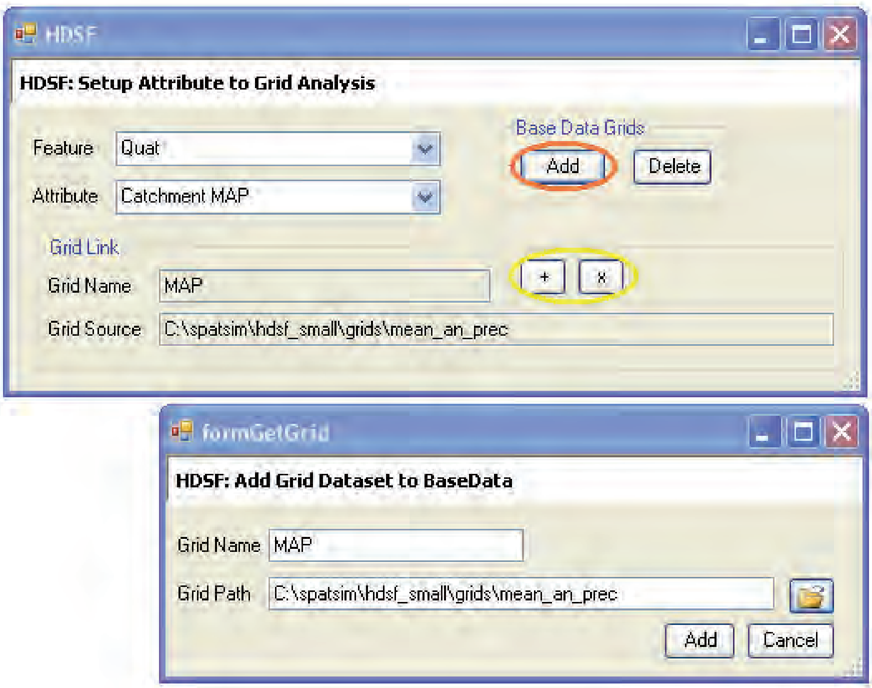

Figure 13: Adding base data grids

Once the grid has been referenced in terms of its name and path it will then appear under the *Attribute* field within a dropdown menu, with its name and source appearing in the *Grid Link* box, thereby allowing it to be chosen as an attribute in the *Setup Attribute to Grid Analysis* window and enabling the user to extract information pertaining to that particular grid coverage.

The two buttons circled in yellow (‘+’ and ‘x’) are used to add and delete links to the grids

The final step in completing a grid analysis simply involves clicking on the *Auto Calc Attributes* button, which runs the application and writes all the applicable data to the relevant table (depending on the type of data) within the spatsim database.

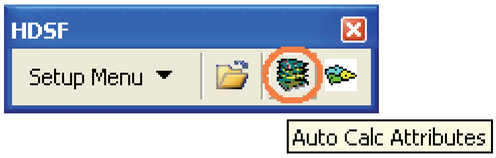

Figure 14: The *Auto Calc Attributes* button

3.2 Area Weighted Coverage Analysis

Area weighted coverage analysis is used to extract and area weight data for individual divisions of a landscape (e.g. quaternary catchments). Unlike the grid analysis the area weighted coverage's are calculated based on polygons, and not on grids, therefore data extractions are carried out on data that falls within the discrete objects view such as land use and crop type.

Once the projects directory has been set and the relevant project loaded (as explained in section 2) click on the *Area Weight Coverage's*, this brings you to the *Area Weight Coverage Attributes* window in which you set the stipulations of the area weighted extractions.

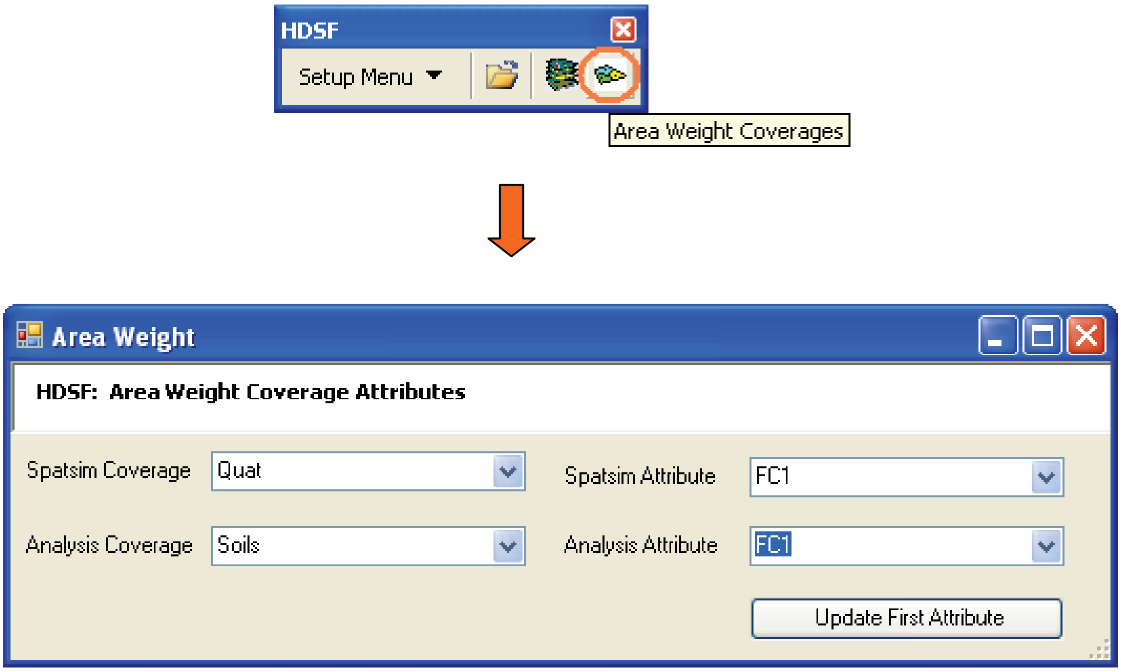

Figure 15: Setting up area weighted coverage analysis

Spatsim Coverage selector refers to the level of detail, with respect to the size of the divisions of the landscape, that you require the data to be averaged on. In the particular example above the level of detail is on a quaternary level.
Analysis Coverage selector is the coverage from which the attributes will be extracted. For example, in Figure 14 above the *Analysis Coverage* is set to soils, which is the coverage from which the data pertaining to attributes specific to that coverage (soils) such as field capacity, wilting point etc. will be extracted and placed into the spatsim database.

The *Spatsim Attribute* selector is involved with referencing of the extracted values and where in the database they will be stored, while the *Analysis Attribute* is the specific attribute that you require the data to be extracted for. In Figure 14, for example, it would be Field capacity 1 (FC1).
It is advisable to ensure that these two fields (*Spatsim Attribute* and *Analysis Attribute*) contain the she same input to avoid confusion.

In the bottom right hand corner of the *Area Weight* window there is a button named *Update First Attribute*. The first time this button is pressed a coverage of the study area representing the *Analysis Coverage* is produced (In the example displayed in Figure 14 the coverage produced would be a soils coverage). From the resulting coverage other variables that pertain to the *Analysis Coverage* can be extracted from the created coverage. In the case of the example in Figure 14 it would be variables pertaining to the soil coverage, therefore variables such as wilting point and soil depth can be extracted without a whole new soils coverage having to be computed in every instance.

Figure 16: Polygon coverage

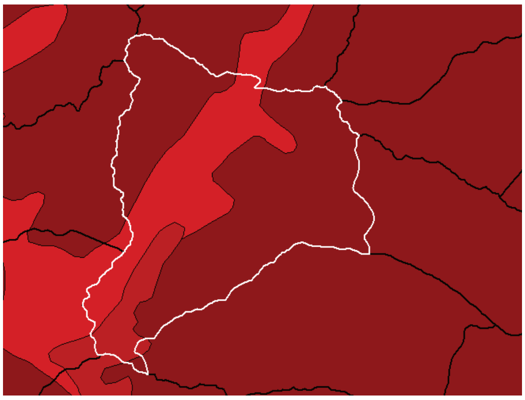

Figure 17: Polygon coverage with quaternary coverage overlayed

Using area weighting the influence that each of the three polygons has within the demarcated quaternary is calculated and an average is given to represent the quaternary.

APPENDIX C

TSAnalysis Tools: User Manual

TSAnalysis

User Manual

Version 1.0
JULY 2011

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Appendix C

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1. INTRODUCTION

The purpose of the TSAnalysis software is to provide a comprehensive and easy to use set of software tools for analysis and display of model input and output time series data stored in different data sources. The data sources currently supported in TSAnalysis are SPATSIM-HDSF project databases, SPATSIM-HDSF Binary files and Dbase files. TSAnalysis has been packaged as software library so that it may be accessed from a variety of modelling tools.

The time series analysis tools that have been included in TSAnalysis are:

- Graphs,
- Statistics,
- Comparative Statistics,
- Frequency Analysis,
- Extreme Value Distributions,
- Run Length Analysis,
- High/Low Period Analysis, and
- Transformations.

2. GENERAL FUNCTIONALITY

TSAnalysis has some functionality that is generic across the different tools, such as selection of a data source and choosing aggregation options. This generic functionality will be described in this chapter before describing the functionality specific to each tool in the subsequent chapters.

2.1 Selecting a Data Source and Time Series Data

In all the tools there will be sections allowing the selection of a data source and the selection of time series data. An example of a window containing a data source selection section and a time series selection section is shown in
Figure **2.1**.

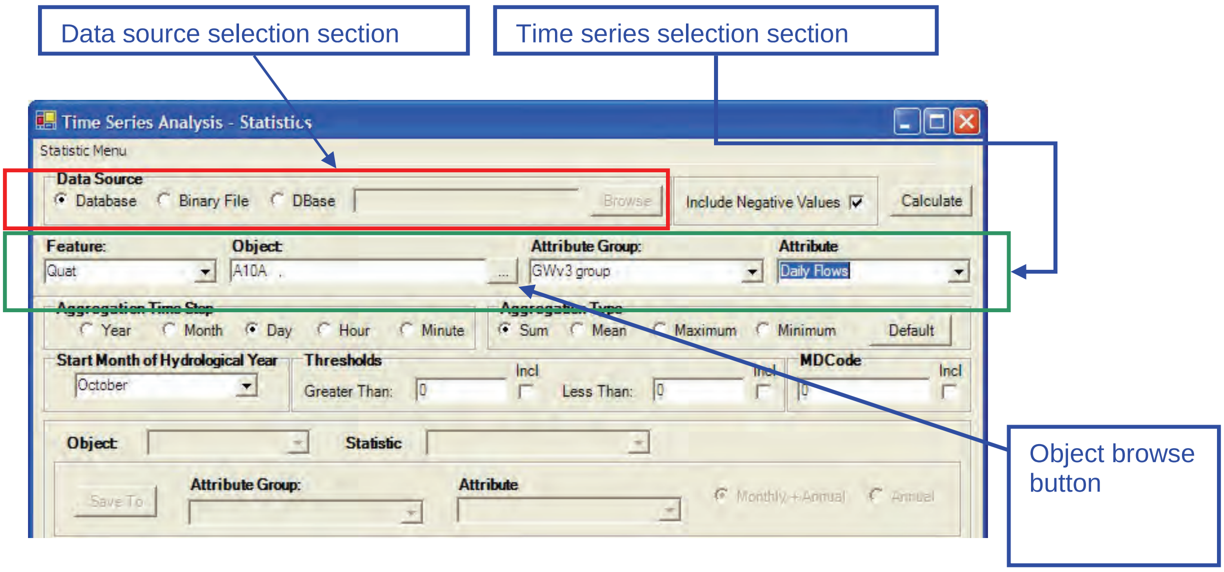

Figure 2.1 Example of data source and time series selection sections on the *Statistics* window

There are three types of data sources, namely SPATSIM-HDSF project databases, SPATSIM-HDSF binary files and Dbase files. To select a data source the user will perform a set of steps for the data source type chosen. The steps carried out to select a time series data attribute are different for each of the different data source types.

2.1.1 SPATSIM-HDSF Project Database

A SPATSIM-HDSF project database can contain time series data. TSAnalysis has functionality to select time series data from a SPATSIM-HDSF project database for analysis. Use the following procedure to select a time series data set from a SPATSIM-HDSF project database:

- Select the *Database* option in the *Data Source* section. The *Browse* button will be enabled in the *Data Source* section.
- Click the *Browse* button and an *Open file dialog window* will be displayed to enable selection of a SPATSIM-HDSF project initialisation (*ini) file. If the file is valid the *Feature* dropdown list will be populated and enabled within the time series selection section.
- Select a feature from the *Feature* dropdown list. The O*bject* browse button and the *Attribute Group* dropdown list are enabled within the time series selection section, once a feature is chosen.
- Click the *Object* browse button and the *Select Objects* window will be displayed. It contains a list of current objects in the *Current Objects* list box. Selecting one or more objects in the *Current Objects* list box, and clicking the add button (**Figure 2.2**), adds the objects to the *Selected Objects* list box. Clicking on the *All* checkbox under the *Current Objects* list box, selects all the objects in the *Current Objects* list box. Selecting one or more objects in the *Selected Objects* list box, and clicking the remove button (**Figure 2.2**), removes the objects in the *Selected Objects* list box. Clicking on the *All c*heckbox under the *Selected Objects* list box will select all the objects, allowing the removal of all objects from the *Selected Objects* list box. Clicking on continue will select object/s in the *Selected Objects* list box to be used in the analysis.
- Select an attribute group from the *Attribute Group* dropdown list in the time series selection section. The *Attribute* dropdown list is enabled once an attribute group has been selected.
- Select a time series attribute from the *Attribute* dropdown list.

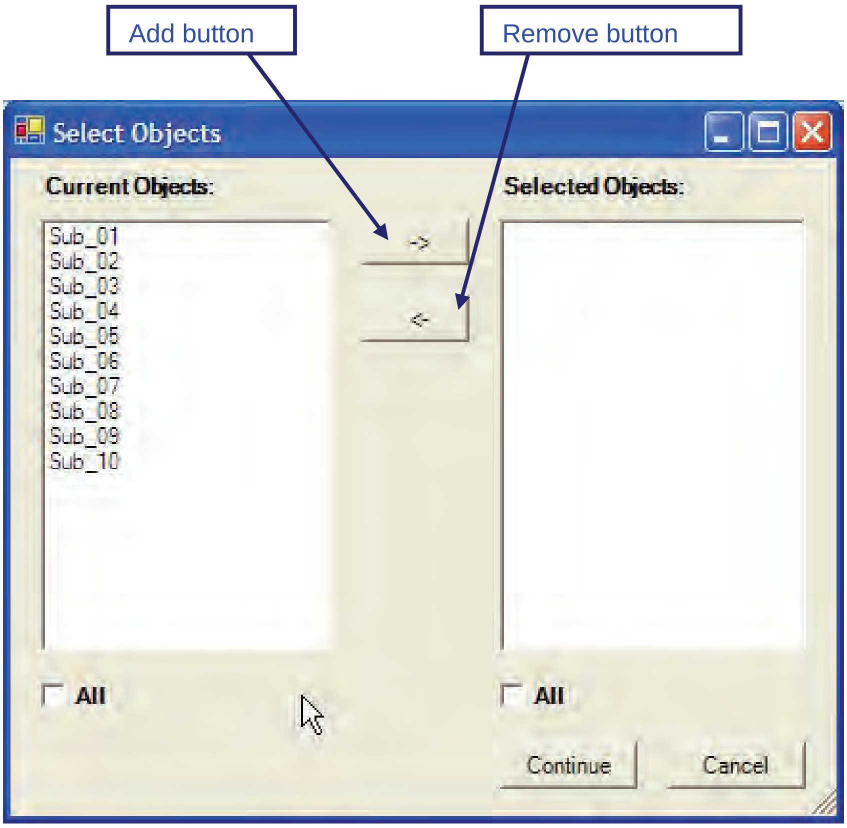

Figure 2.2 The *Select Objects* window

2.1.2 SPATSIM-HDSF Binary Files

SPATSIM-HDSF Binary files created by some SPATSIM-HDSF compliant models contain time series data. TSAnalysis has functionality to select the time series data from a SPATSIM-HDSF Binary file for analysis. Use the following procedure to select a time series data set from a SPATSIM-HDSF Binary file data source:

- Select the *Binary File* option in the *Data Source* section. The *Browse* button will be enabled in the *Data Source* section.

Click the *Browse* button and an *Open file dialog window* will be displayed to enable selection of a SPATSIM-HDSF Binary file. If the file is valid the *Attribute* dropdown list within the time series selection section will be enabled. With a SPATSIM-HDSF Binary file the *Feature*, *Object* and *Attribute Group* dropdown list will be disabled because the SPATSIM-HDSF Binary file only contains time series attribute data for one object. An example of a SPATSIM-HDSF Binary file chosen as a data source is shown in

- **Figure 2.3**.
- Select a time series attribute from the *Attribute* dropdown list.

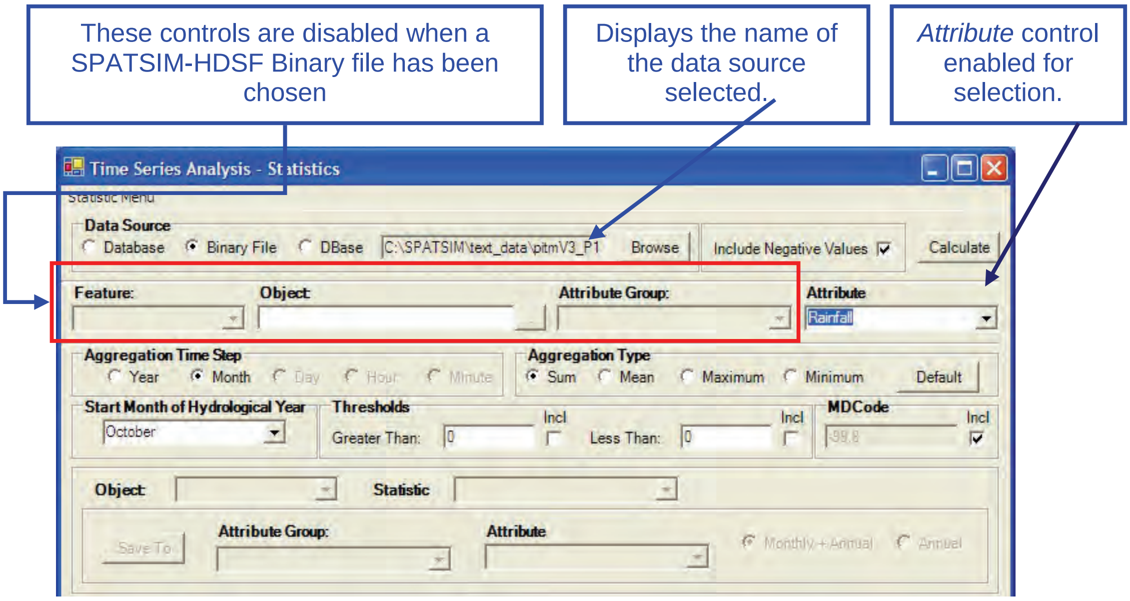

Figure 2.3 Example of a SPATSIM-HDSF Binary file data source and time series selected on the *Statistics* window

2.1.3 Dbase Files

A Dbase file may contain time series data. TSAnalysis has functionality to select the time series data from a Dbase file for analysis. Use the following procedure to select a time series data set from a Dbase file data source:

- Select the *Dbase* option in the *Data Source* section. The *Browse* button will be enabled in the *Data Source* section.
- Click the *Browse* button and an *Open file dialog window* will be displayed to enable selection of a Dbase file. Select a Dbase file.
- If the file is valid, a window will be displayed to enable selection of a date and value from the Dbase file as shown in Figure 2.4. Select a date column from the *Date Column* dropdown list and a value column from the *Value Column* dropdown list. Clicking on the *Continue* button on this window will select the time series attribute.

In the case of a Dbase file the *Feature*, *Object*, *Attribute Group* and *Attribute* controls in the time series selection section will be disabled. The time series attribute has already been chosen in the previous step. The time series attribute name will be displayed in the disabled *Attribute* control. An example of a Dbase file selected as a data source is shown in

- **Figure 2.5**

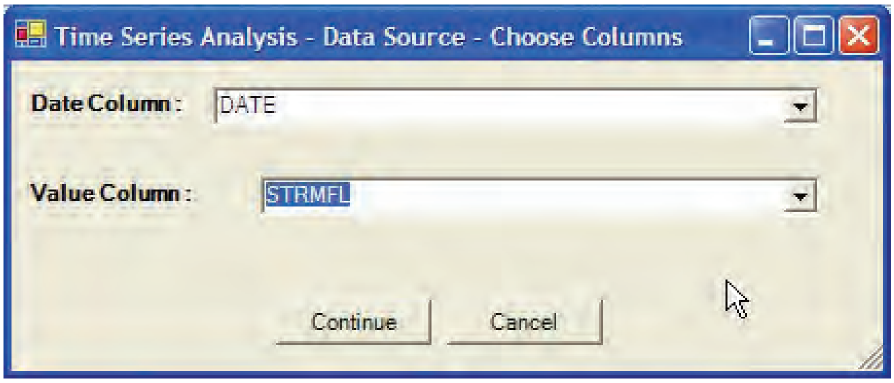

Figure 2.4 The window used to select date and value columns from a Dbase file

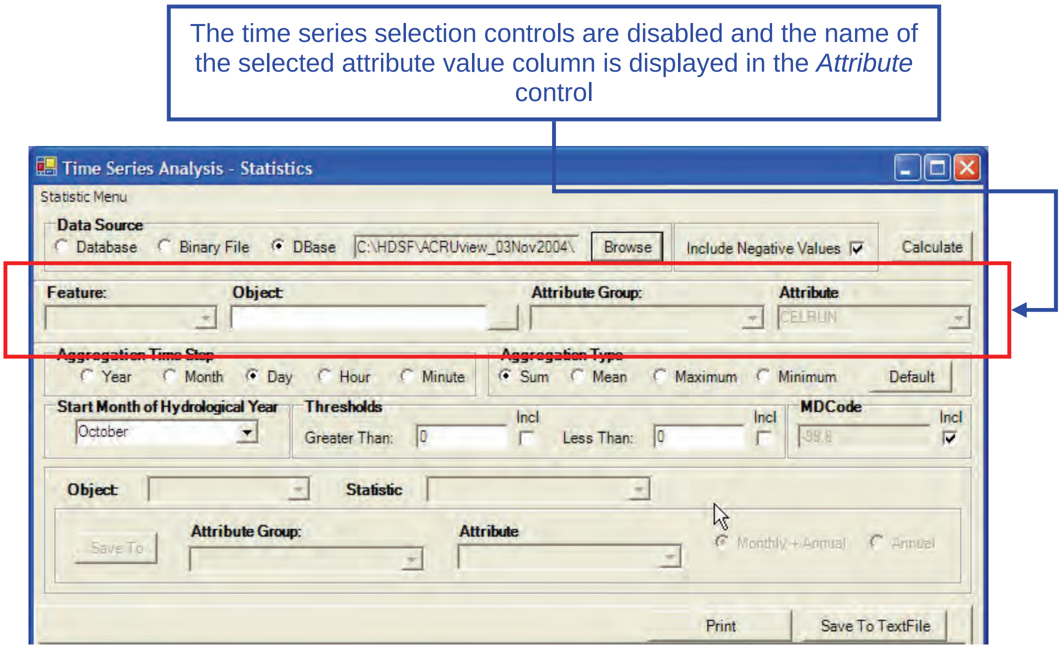

Figure 2.5 Example of a Dbase data source and time series selected on the *Statistics* window

2.2 Aggregation Options

When analysing time series using data analysis tools the time series data is often aggregated to a longer time step, usually by summing or averaging. Different time series data is aggregated in different ways, for example rainfall is summed and temperature is averaged. In all the tools there will be a section enabling the selection of aggregation options. An example of a window containing the aggregation options section is shown in Figure 2.6.

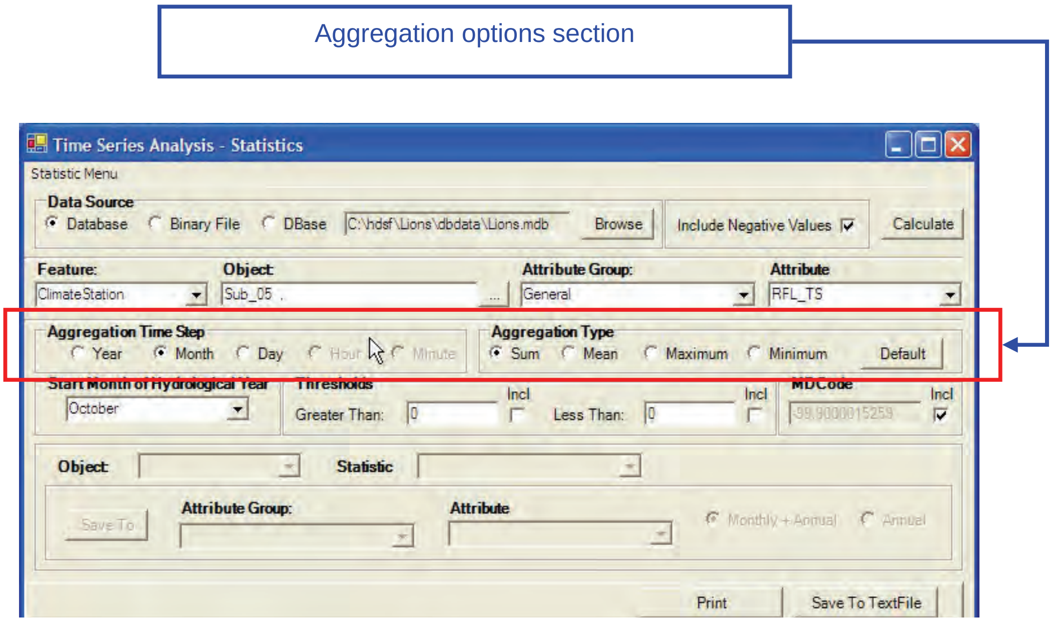

Figure 2.6 Example of the aggregation options section on the *Statistics* window

Based on the actual time step of the time series certain *Aggregation Time Step* options will be greyed out. For example, for a daily time step time series the data can only be aggregated up to monthly and yearly time steps. The way the data is aggregated is dependent on the *Aggregation Type* selected. In
Figure 2.6 **an example of a daily time step time series is shown, which will be aggregated from daily to monthly. The *Aggregation Time Step* options for minute and hourly are disabled in**
Figure 2.6, because it is a daily time step time series.

If the time series data needs to be aggregated to a longer time step, select an aggregation time step and aggregation option type relevant to the selected time series.

2.3 Analysis Template File

For all tools within TSAnalysis, once the data source and time series has been selected, and the analysis carried out, the setup (the data source, options and analysis parameters selected for that analysis) can be saved. This information is saved to a file called the Analysis Template File (ATF). The purpose of saving this information is to save the user from having to go through the whole process of selecting the data source, options and analysis parameters if an analysis needs to be repeated. Once saved, an analysis can be easily redone by selecting it from the ATF file. The process of saving and opening an ATF file is generic across all the tools except for the Graph tool. The steps for the Graph tool are described in Section 3.3.

For each of the tools the main menu contains options to open an analysis in an existing template file, save to a new ATF file, and add/save to existing ATF file. The Statistics tool will be used to describe the steps for each option. The steps are the same for all the tools.

2.3.1 Open an Analysis File

This section describes the opening of an analysis which is stored within an ATF file.

Click on the *Statistic Menu* and select the *Open Analysis* menu option as shown in

- **Figure 2.7**.
- An *Open* file dialog is displayed. Using the *Open file dialog,* navigate to the ATF file you would like to open, select it and then click the *Open* button.

A *Select* window will be opened, allowing the selection of an analysis that has been saved in the ATF file. An example of this window is the *Statistics* select window show in

- **Figure 2.8**.
- Select an analysis and click the *Open* button. The data will be loaded into the analysis tool you are dealing with and the analysis will be carried out automatically.

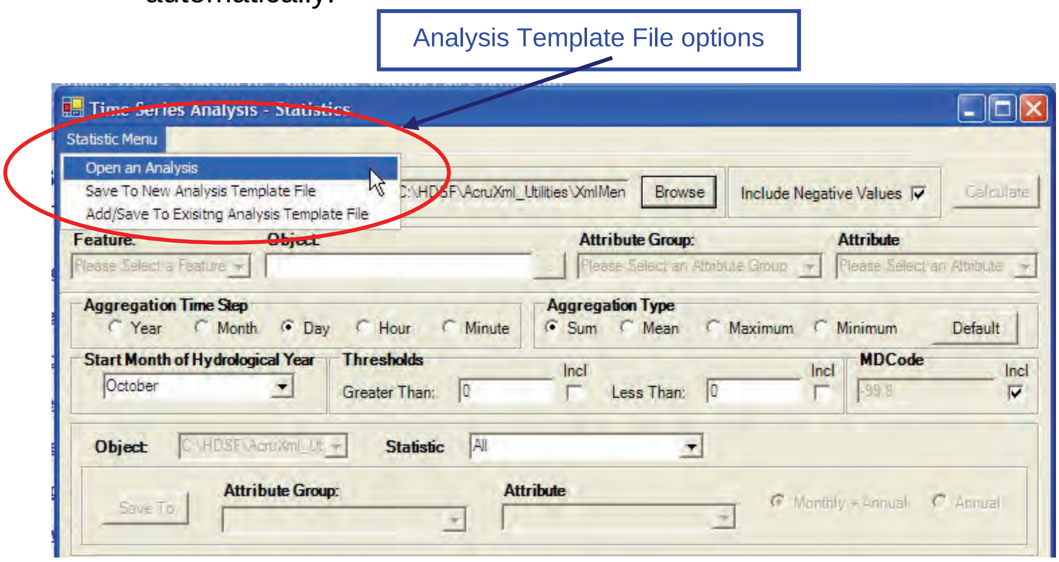

Figure 2.7 Example of a main menu containing the Analysis Template File options in the *Statistics* window

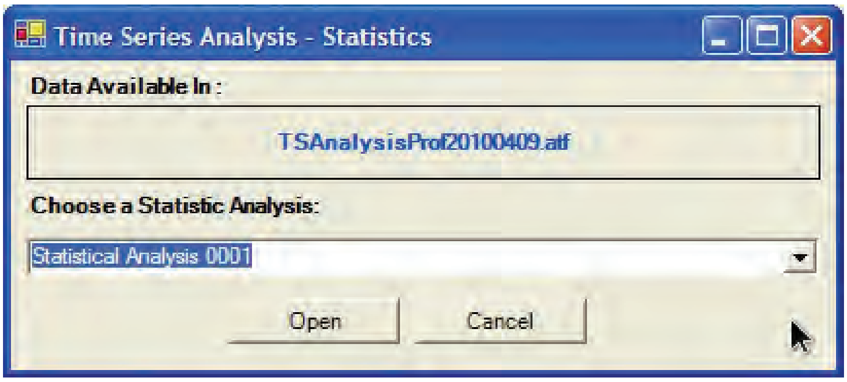

Figure 2.8 Example of a *Statistics* selection window

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2.3.2 Save To New Analysis Template File

Once an analysis has been carried out, this setup can be saved to an ATF file. Click on the *Statistic Menu* and select the *Save To New Analysis Template File* menu option. An *Add Name window* will be opened. In the case of *Statistics* it will be a *Statistic – Add Name* window as shown in

Figure 2.9. Enter a unique name for the analysis and then click on the *Continue* button. A *Save* file dialog will be opened. A default name for the ATF file already appears in the *Filename* field of the *Save* dialog box. Click the *Save* button, to save the analysis setup data.

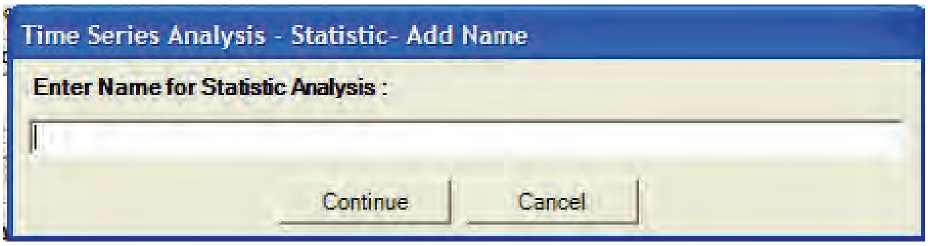


Figure 2.9 Example of *Statistic - Add Name* window

2.3.3 Add/Save To Existing Analysis Template File.

Once an analysis has been carried out, this setup can be saved to an existing ATF file. Click on the *Statistic Menu* and select the *Add/Save To Existing Analysis Template File* menu option. An *Add Name* window will be opened. In the case of *Statistics* it will be a *Statistic – Add Name* window as shown in

Figure 2.9. Enter a unique name for the analysis data and click on the *Continue* button. A *Save* dialog box will be opened. Select the ATF file to save to and click the *Save* button, to save the analysis setup data.

3. GRAPHS

The *Time Series Analysis – Graphs* tool enables one or more sets of time series data to be plotted for visual analysis by the user. An example of the *Time Series Analysis – Graphs* window is shown in **Figure 3.1**. The window contains two sets of graph axes separated by an adjustable splitter. The adjustable splitter is used to increase/decrease the size of the area of one graph and at the same time will decrease/increase the other graph area size. There are controls for each of the graph axes to zoom and scroll to selected portions of a time series. On each set of graph axes one or more time series may be plotted as either line or bar graphs.

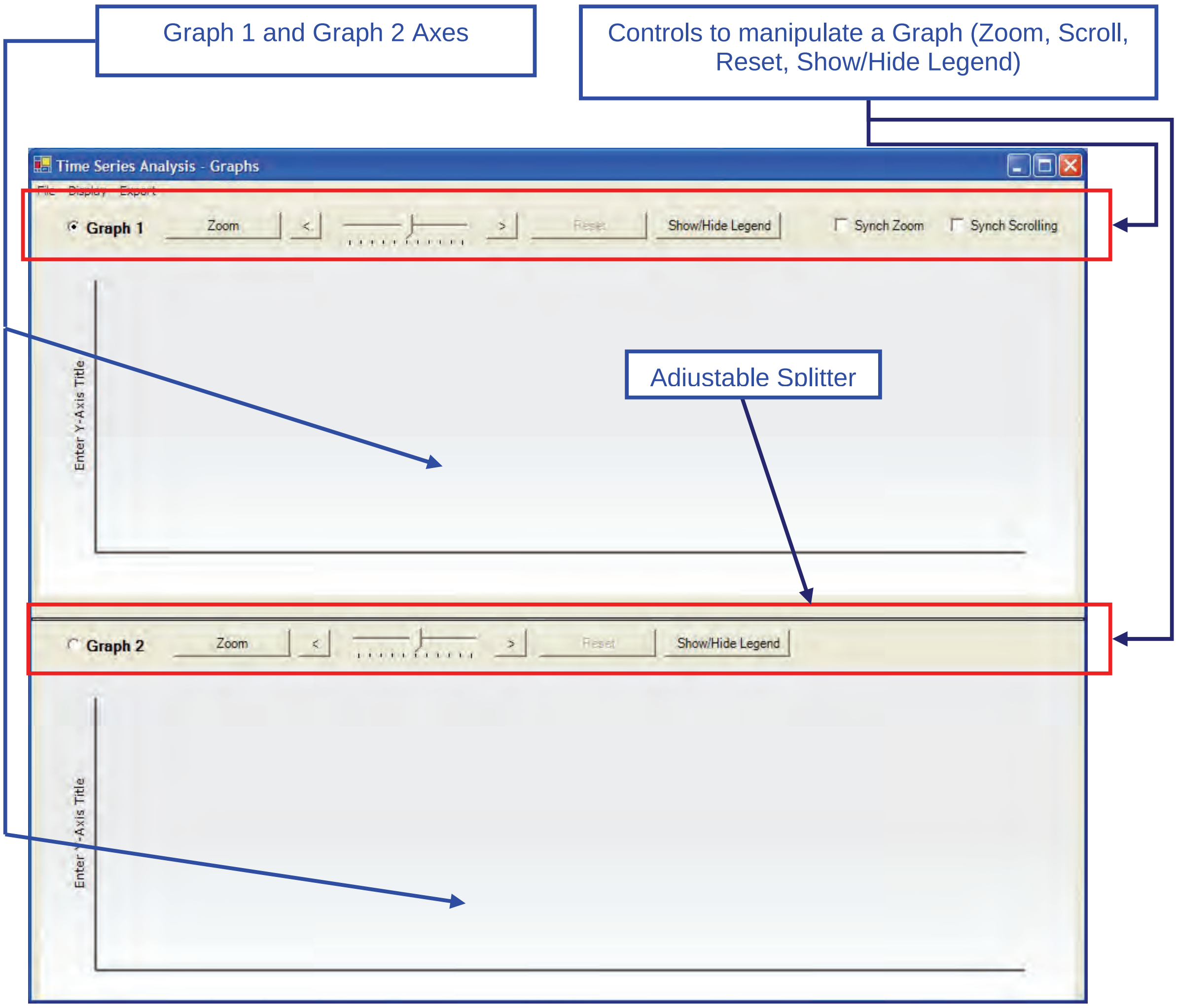


Figure 3.1 Example of the *Time Series Analysis – Graphs* window.

3.1 Plotting Time Series Data

Plotting time series data on a graph provides a visual representation of the data for visual analysis. The steps below describe how to plot a time series dataset on a selected graph axes:

- Select *Graph 1* or *Graph 2*.

Select *File, Add New Time Series* from the main menu. The *Time Series Analysis - Graphs - Add Time Series* window will be opened as shown in

- **Figure 3.2**.
- Select a data source and time series as described in Section 2.1.
- Enter a short name in the *Short Name* field. A default short name already appears in the field, which is made up of the selected time series attribute name and the selected object name.
- Select a suitable date range. The start and end dates of the time series dataset are already set as the current *Date Range*. If a time period within the time series date range is required, this can be done by selecting the appropriate *Start Date* and *End Date*.
- Select a *Graph Type*. Selecting the *Line* option will plot the data as a line graph, and selecting the *Bar* option will plot a bar graph.
- Set the *Scaling Factor*. This factor is applied to each value in the time series data, by multiplying each value by the scaling factor value. The default scaling factor value is 1.0.
- Specify a missing data value (*MDCode)* so that data points less than the missing data value are not included in the analysis.
- Select a *Series Type* option:
    - *Single Series* – The entire time series dataset is plotted as a single series.

***Multiple Series* – If this option is selected then the lists to select months and years are enabled as shown in**

- - **Figure 3.3**. Clicking on the *Invert Month Selection* button, will invert the current selection in the months list. Clicking on the *Invert Years Selection* button, will invert the current selection in the years list.

Click the *Continue* button to add the time series dataset to the graph. The data will be added to the graph that was selected at the beginning of this section. An example of a graph with a plotted time series data set is shown in

- **Figure 3.4**.

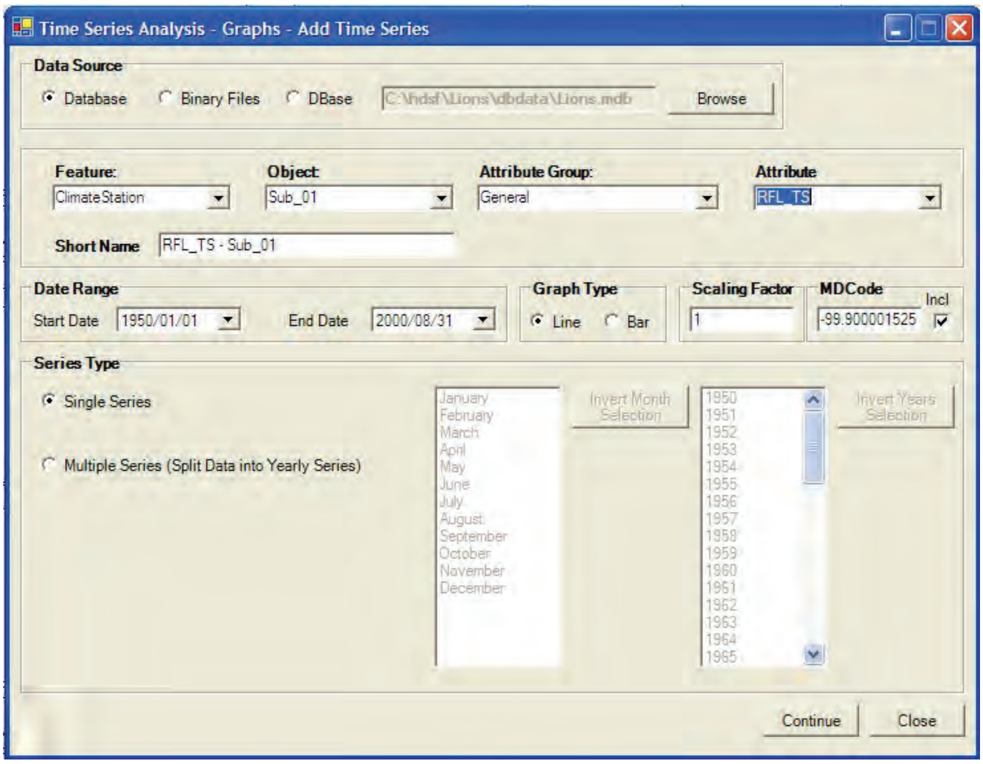


Figure 3.2 Example of the *Time Series Analysis - Graphs - Add Time Series* window

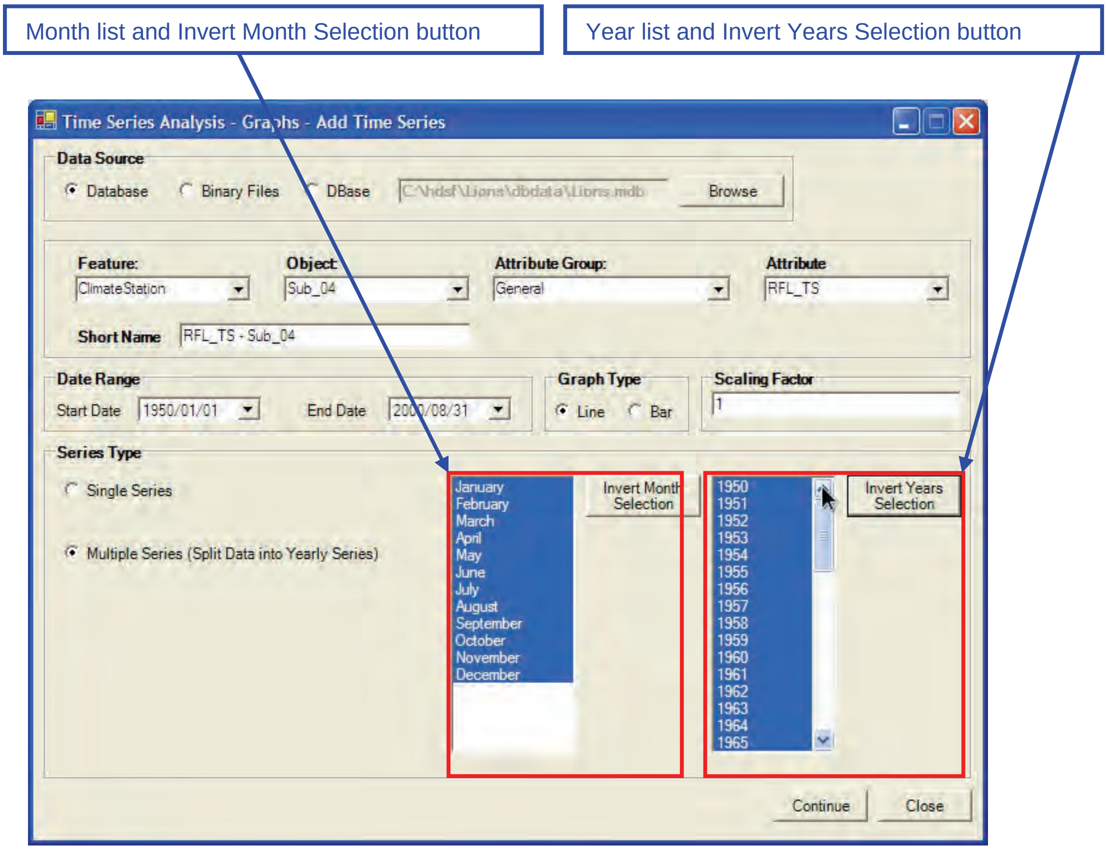


Figure 3.3 *Time Series Analysis - Graphs - Add Time Series* window with Multiple Series type selected

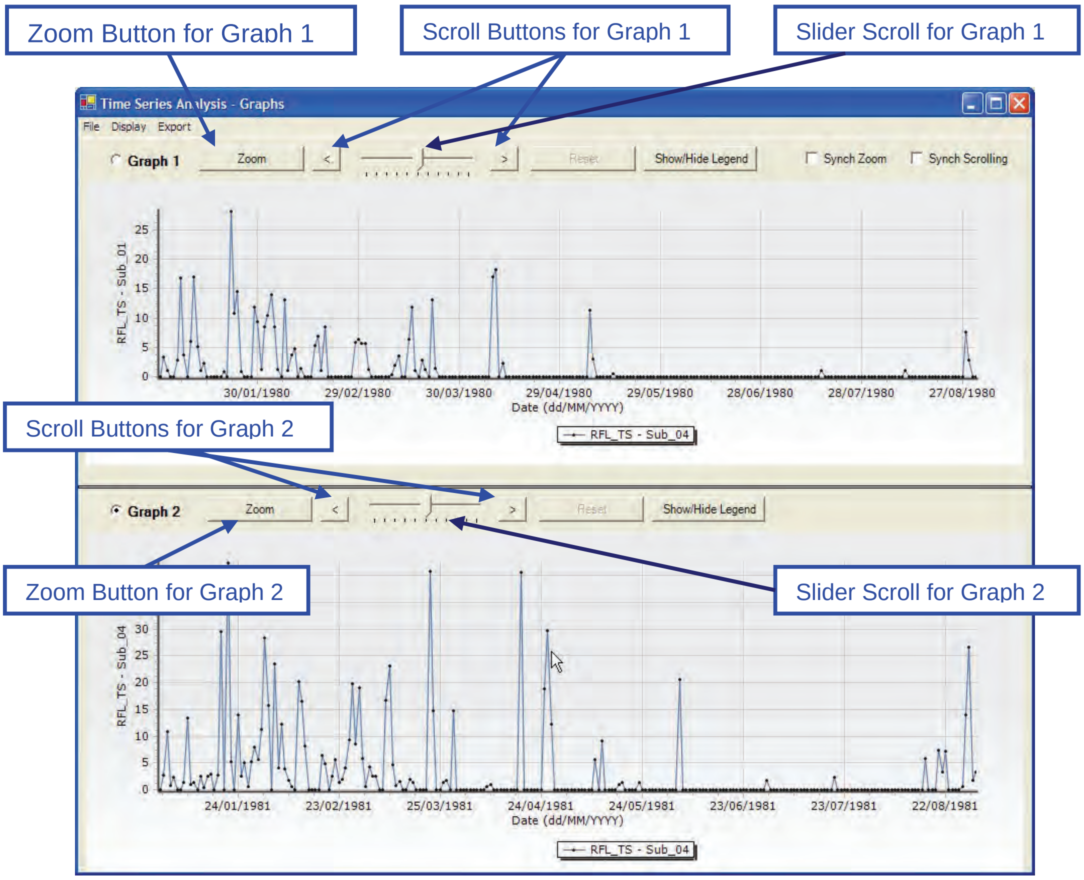


Figure 3.4 Example of the *Time Series Analysis – Graphs* window with a time series plotted in each graph axes

3.2 Controls on the Time Series Analysis – Graphs Window

On the *Time Series Analysis – Graphs* window there are controls to manipulate data plotted on the graph axes. These controls are described in more detail as follows:

***Zoom* button - Each set of graph axes has its own *Zoom* button as shown in**

- **Figure 3.4**. Clicking on the *Zoom* button will zoom into portions of the data plotted on the graph axes. If we check the *Synch Zoom* option and then clicking on either of the *Zoom* buttons on the window will result in synchronized zooming of data plotted on both graph axes. The amount of zoom applied to both graph axes is the same when the *Synch Zoom* option is checked.

Scroll buttons - Each set of graph axes has its own set of scroll controls as shown in

- **Figure 3.4**. Clicking on the scroll buttons will scroll the plotted data along the date axis. Checking the *Synch Scrolling* option and clicking on any of the scroll buttons, will result in synchronized scrolling of data on the both sets of graph axes. The amount the data is scrolled and the section along the date axis is the same for synchronized scrolling. Scrolling can also be done using the slider controls between the scroll buttons. This allows for variable scrolling of data. The further you slide the control a greater percentage of the data is scrolled. This can also be used for synchronized scrolling.

***Show/Hide Legend* button - Each graph axes has its own *Show/Hide Legend* button as shown in**

- **Figure 3.4**. Clicking on the *Show/Hide Legend* button hides the legend if it is displayed or shows the legend if it is hidden. Hiding the legend allows for more space for the data to be plotted on the graph axes, resulting in better plots of data.
- *Reset* button - Each graph axes has its own *Reset* button. Clicking on the *Reset* button removes any zoom or scroll applied to a set of graph axes.

3.3 File Menu Options

This section describes functionality found under the file menu option. Clicking on *File* in the main menu will provide several options as shown in **Figure 3.5**.

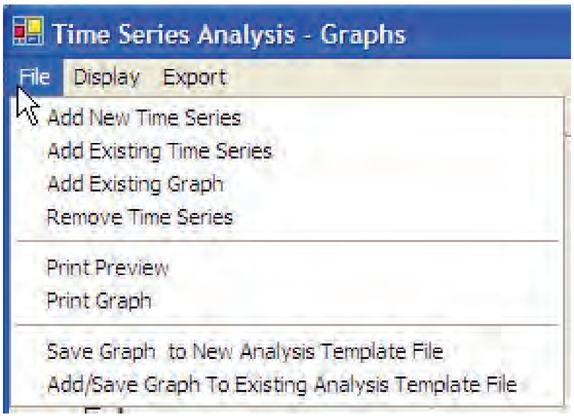


Figure 3.5 *File* menu options for *Time Series Analysis - Graphs* window

These options briefly are briefly described as follows:

- *Add New Time Series* - Refer to Section 3.1.

***Add Existing Time Series* - this is similar to opening an ATF File as described in Section 2.3.1. The difference is in the selection of a time series within a graph setup. A graph setup contains one or more time series. The window for selecting data is shown in**

- **Figure 3.6**. A graph needs to be selected and then an existing time series within the graph setup can be selected. Clicking the *Add* button will plot the time series on the graph axes chosen.
- *Add Existing Graph* - this is discussed in Section 2.3.1.

- *Remove Time Series* - This removes a specified time series that is plotted in the selected set of graph axes.
- *Print Preview* - Shows the print preview of the selected set of graph axes.
- *Print Graph* - Prints the selected set of graph axes.
- *Save Graph to New Analysis Template File* – Refer to Section 2.3.2 above.
- *Save Graph to Existing Analysis Template File* – Refer to Section 2.3.3 above.

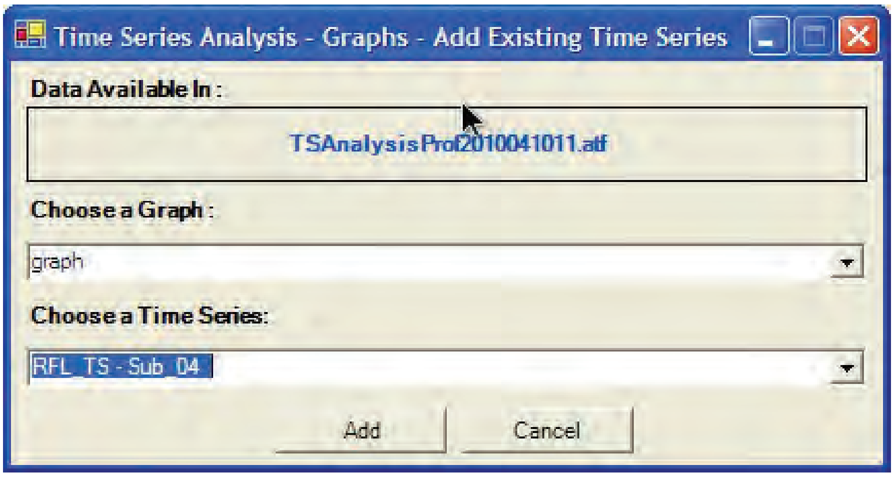


Figure 3.6 *Time Series Analysis - Graphs - Add Existing Time Series* window

3.4 Display Menu Options

The main menu has an option called *Display*. Options that manipulate the display of a graph are found under this main menu option as shown in
Figure 3.7.

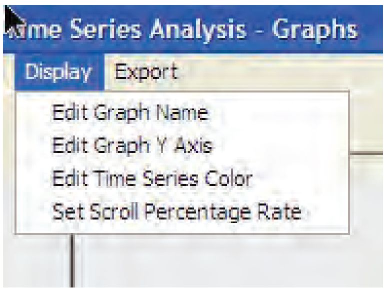


Figure 3.7 *Display* menu options for *Time Series Analysis - Graphs* window

These options are briefly described as follows:

- *Edit Graph Name* - Each graph has a name. This name is used to identify the graph within an ATF. This option enables the graph name to be edited.

- *Edit Graph Y-Axis* - This option enables the Y-Axis label to be edited. The default Y-Axis label is the short name entered when adding a time series to a set of graph axes.
- *Edit Time Series Colour* - To create a graph which displays data more effectively, the colour of certain time series plotted may need to be changed. This option enables the colour of a time series to be changed.
- *Set Scroll Percentage Rate* - The rate at which data is scrolled is set in this option. The default scroll percentage is 10 percent.

3.5 Export Menu Options

Data plotted on the graphs can be exported to different formats. This functionality can be found under the main menu option *Export*. The *Export* menu options are shown in **Figure 3.8**.

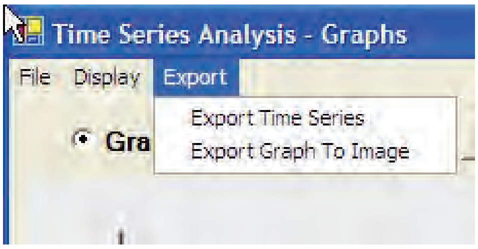


Figure 3.8 *Export* menu option for *Time Series Analysis - Graphs* window

These options are briefly described as follows:
***Export Time Series* – This option enables a selected time series from a graph to be exported to a comma separated file (*CSV*) or a text file. Selecting this option from the main menu displays the window shown in**
Figure 3.9**. Once a time series has been selected, click on the *Accept* button and the window in**

- **Figure 3.10** will be displayed. Select a *File Type*. The *Date Column Name* and *Value Column Name* fields enable the column names to be edited. The default *Date Column Name* is 'Date'. The default *Value Column Name* is the Y-Axis title. The *Date Format* selector enables the users to select the format with which the dates will be written to the file. The format of the date and time column can be *YYYYMMddhhmmss* and *ddMMYYYYhhmmss* where *YYYY* represents the year, *MM* represents the month, *DD* represents the day, *hh* represents the hour, *mm* represents the minute and *ss* represents the seconds. Clicking on the *Export* button will create the new CSV or text file containing the time series data. The *Text* file type option is similar to the *CSV* option except that there is an additional *Text Delimiter* field as shown in Figure 3.11 which enables a text delimiter character, for example "," or ";", to be specified.
- *Export Graph to Image* – This option enables a selected graph to be exported to an image in one of a selection of image formats.

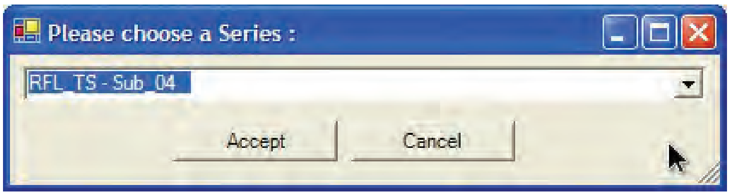


Figure 3.9 The *Please choose a Series* window

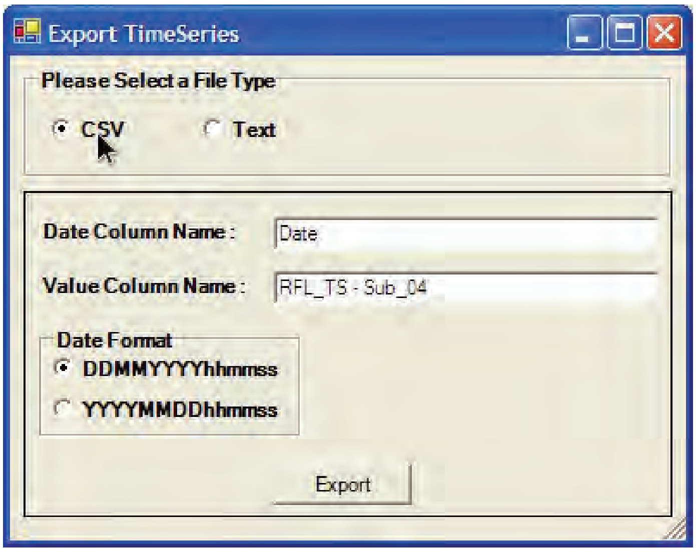


Figure 3.10 *Export TimeSeries* window with the *CSV* option selected

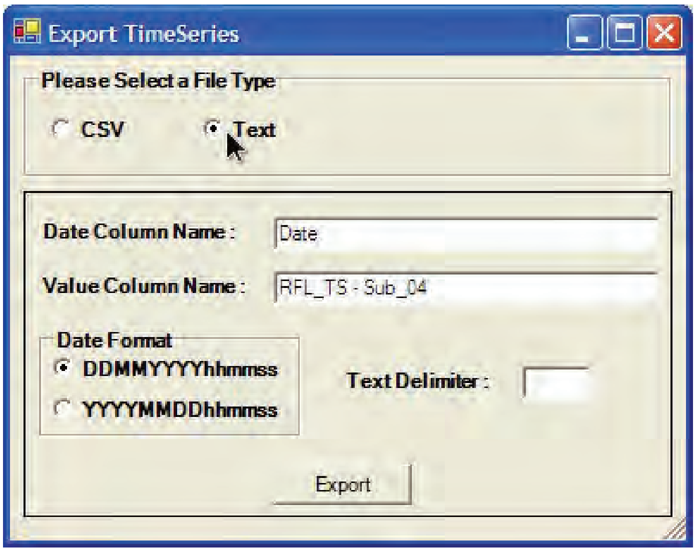


Figure 3.11 *Export TimeSeries* window with the *Text* option selected

4. STATISTICS

The *Time Series Analysis – Statistics* tool enables a set of useful month-by-month and annual statistics for a selected time series to be calculated, graphed and saved. The following statistics are calculated:

(i) sum,
(ii) mean,
(iii) median,
(iv) maximum,
(v) minimum,
(vi) number of data points,
(vii) variance,
(viii) standard deviation,
(ix) coefficient of variation,
(x) skewness,
(xi) kurtosis,
(xii) number of values less than a user specified threshold value, and
(xiii) number of values greater or equal to a user specified threshold value.

An example of the *Time Series Analysis – Statistics* window is shown in
Figure 4.1. This window consists of two main sections, the time series selection and options panel at the top, and the statistics *Table* and *Graph* tabbed pages at the bottom. The procedure to perform a statistical analysis is as follows;

- Select a data source and a time series to be analysed, as described in Section 2.1.
- Select an aggregation time step and aggregation option type relevant to the selected time series as described in Section 2.2.
- Select the start month for the hydrological year. The default is set to October.
- Set upper and lower threshold values to calculate the number of values in the time series that fall outside these thresholds.
- Specify a missing data value so that data points less than the missing data value are not included in the analysis.
- Once these options have been set, a statistical analysis can be performed by clicking on the *Calculate* button.

Select the object in the save and view options area of the window shown in

- **Figure 4.1** to view the results. The results will be shown in the *Table* and *Graph* tabbed pages at the bottom of the window.
- The statistics for the selected object may be printed or saved to a text file.
- If the data source is *Database* (a SPATSIM-HDSF database) then there are options in the save and view Options area to save the results to an array data type. The monthly and annual or just annual data can be saved to the array data type.

If the *Table* tab is active then one or all of the calculated statistics for the selected object may be selected to be displayed in the data grid at the bottom of the window as shown in Figure 4.1**. If the *Graphs* tab is active then one of the calculated statistics for the selected object may be selected to be displayed in a graph at the bottom of the window as shown in**

- **Figure 4.2**. The graph can be printed by clicking on the *Print* button within the *Graphs* tab or saved to an image file by clicking on the *Save To Image File* button within the *Graphs* tab.
- This setup for the analysis can be saved to an ATF as described in Section 2.3.2 and Section 2.3.3.

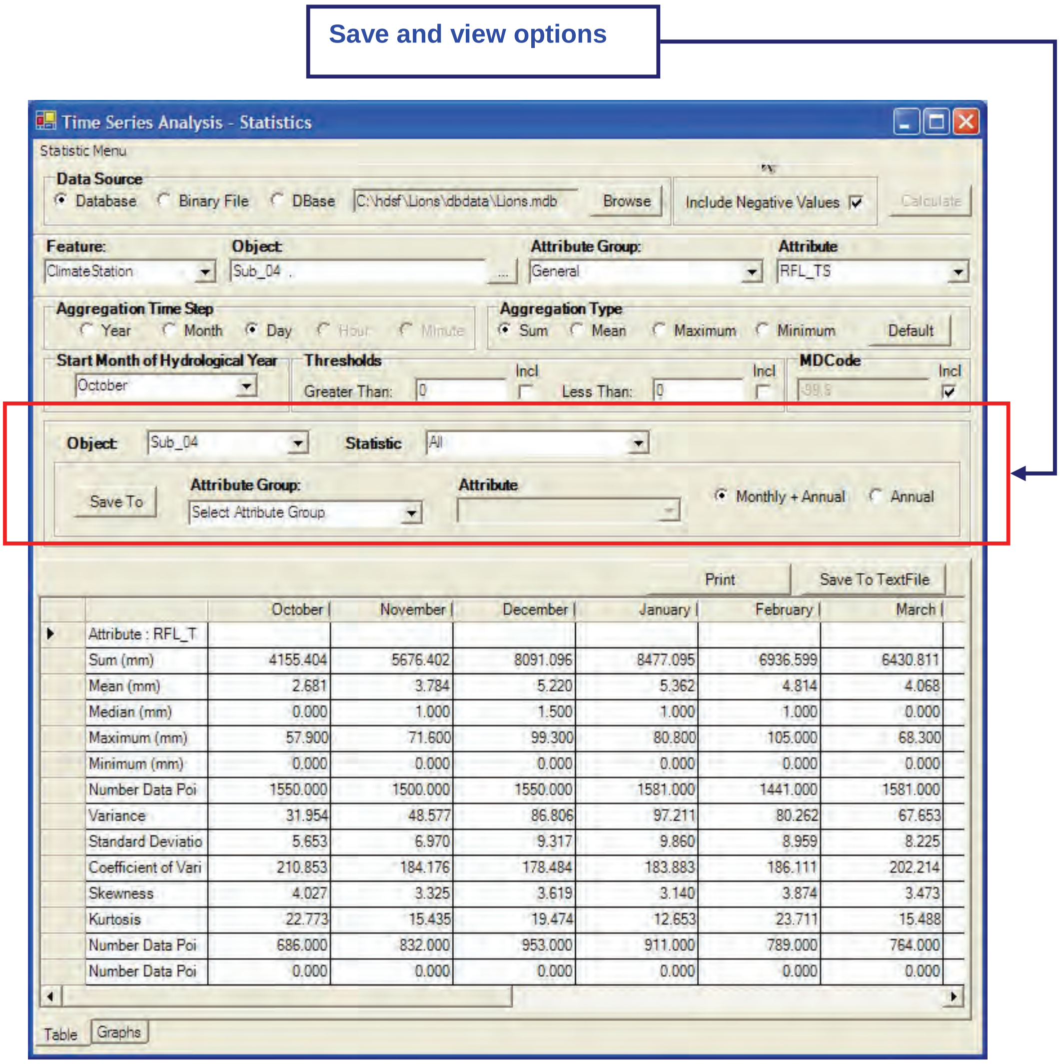


Figure 4.1 Example of the *Time Series Analysis – Statistics* window

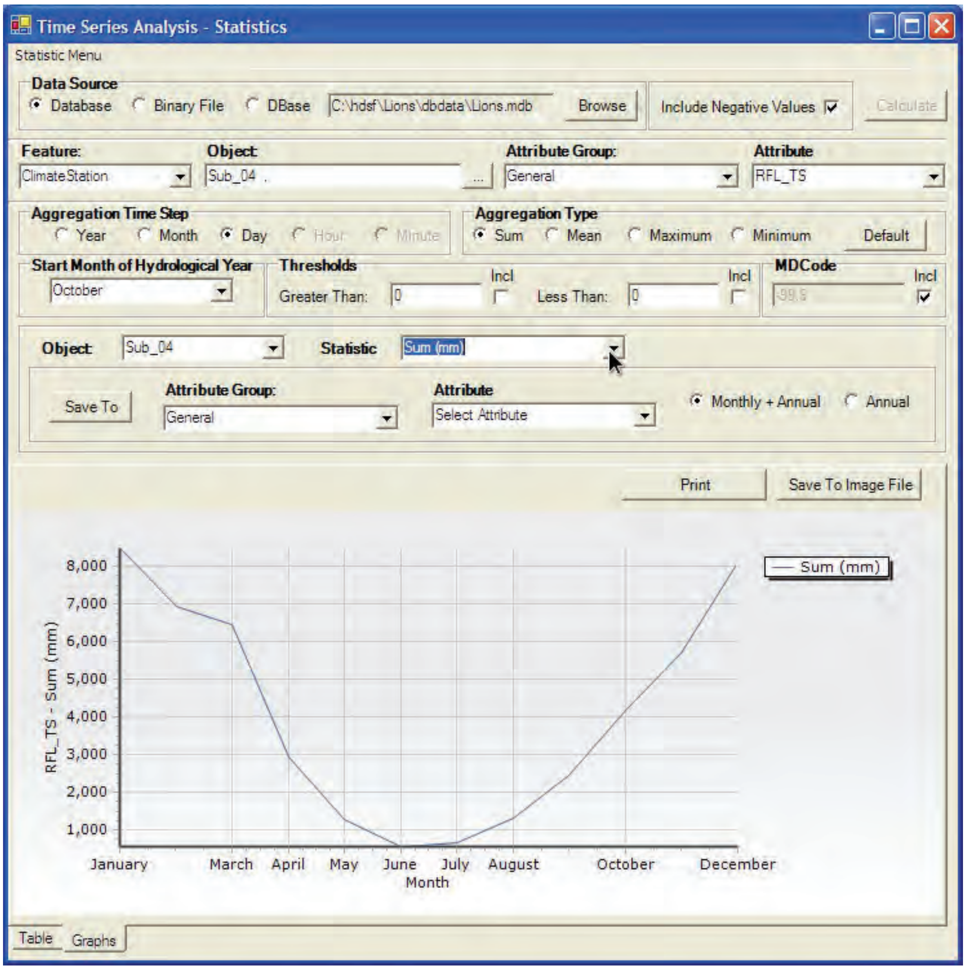


Figure 4.2 Example of the *Graphs* tab on the *Time Series Analysis – Statistics* window

5. COMPARATIVE STATISTICS

The *Time Series Analysis - Comparative Statistics* tool enables the calculation of conservation and regression statistics between two time series, typically time series of observed and simulated data, and to create a scatter plot of the data in these two time series.

The following conservation statistics are calculated:

(i) sum (Attribute A and Attribute B),
(ii) average error,
(iii) mean (Attribute A and Attribute B),
(iv) percentage difference between means,
(v) t statistic for comparing means,
(vi) variance (Attribute A and Attribute B),
(vii) percentage difference between variances,
(viii) standard deviation (Attribute A and Attribute B),
(ix) percentage difference between standard deviations,
(x) standard error (Attribute A and Attribute B),
(xi) percentage difference between standard errors,
(xii) total root mean square error (RMSE),
(xiii) coefficient of variation (Attribute A and Attribute B),
(xiv) percentage difference between coefficients of variation,
(xv) skewness coefficient (Attribute A and Attribute B),
(xvi) percentage difference between skewness coefficients
(xvii) kurtosis coefficient (Attribute A and Attribute B),
(xviii) percentage difference between kurtosis coefficients, and
(xix) t statistic for correlation testing.

The following regression statistics are calculated:

(i) correlation coefficient (Pearson's r),
(ii) regression coefficient (slope),
(iii) regression intercept,
(iv) total sum of squares (SST),
(v) sum of squares due to regression (SSR),
(vi) residual sum of squares (SSE),
(vii) computer rounding error (SST - (SSR + SSE)),
(viii) coefficient of determination (R^2),
(ix) coefficient of efficiency, and
(x) coefficient of agreement.

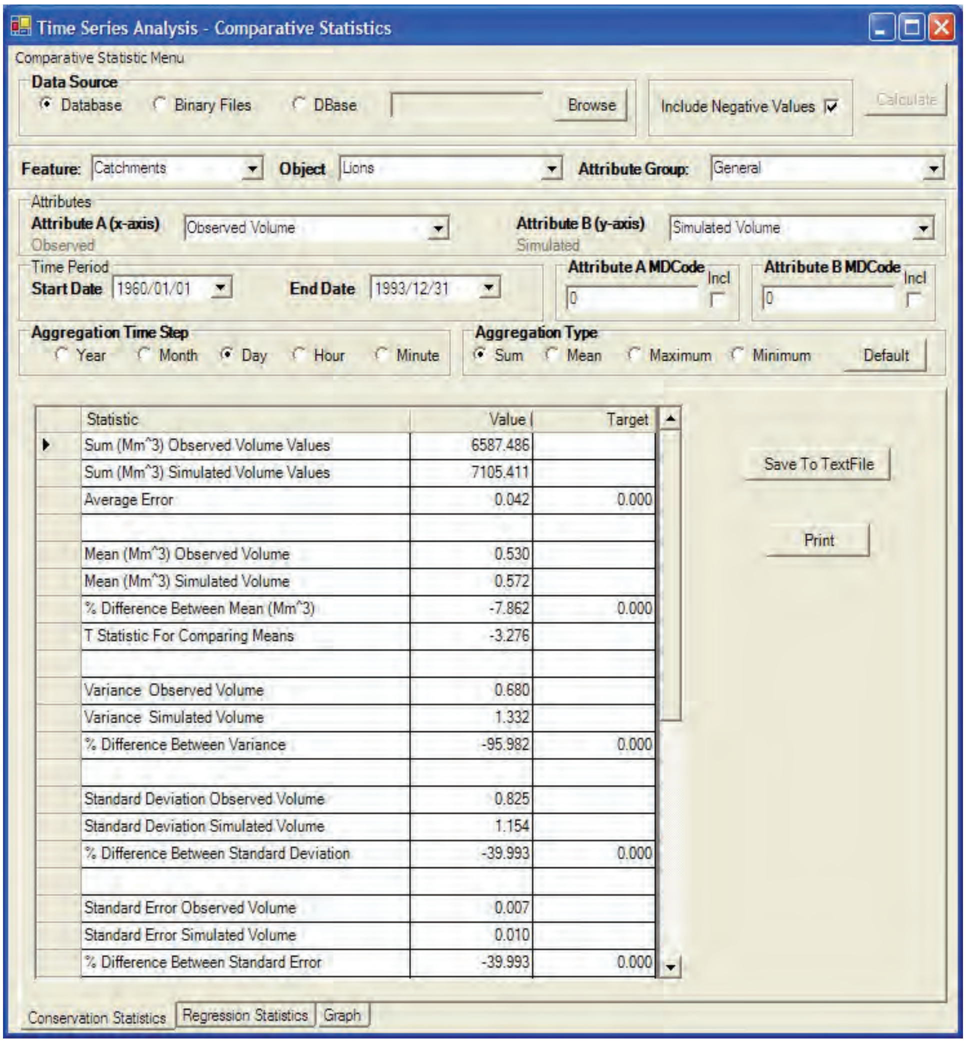
An example of the *Time Series Analysis – Comparative Statistics* window is shown in **Figure 5.1**. This window consists of two main sections, the time series selection and options panel at the top, and the *Conservation Statistics*, *Regression*

Statistics and *Scatter Plot* tabbed pages at the bottom. The procedure to perform a comparative statistical analysis is as follows:

- Select a data source and a time series to be analysed, as described in Section 2.1. Note for the case of a *Database* data source being used, instead of just selecting one time series attribute, there are two selections that need to be made, that is the observed time series attribute (*Attribute A*) and simulated time series attribute (*Attribute B*).
- Selection of a time period within the chosen time series maybe required. This can be achieved by selecting the start and end date of the time period required.
- Specify a missing data value so that data points less than the missing data value are not included in the analysis. A missing data value needs to be set for both observed and simulated attributes.
- Select an aggregation time step and aggregation option type relevant to the selected time series. Further details about these choices are described in Section 2.2.
- Once these options have been set, a comparative statistical analysis can be carried out by clicking on the *Calculate* button.

The results may be viewed in the *Conservation Statistics*, *Regression Statistics* and *Scatter Plot* tabbed pages at the bottom of the window. An example of the *Conservation Statistics* tab is shown in
Figure 5.1**, an example of the *Regression Statistics* tab is shown in**
Figure 5.2 **and an example of the *Scatter Plot* tab is shown in**

- **Figure 5.3**.
- The results may be printed or saved to a text file. In the case of the scatter plot, the graph can be printed or saved to an image file.
- This setup for the analysis can be saved to an ATF as described in Section 2.3.2 and Section 2.3.3.



Statistic	Value	Target
Sum (Mm^3) Observed Volume Values	6587.486	
Sum (Mm^3) Simulated Volume Values	7105.411	
Average Error	0.042	0.000
Mean (Mm^3) Observed Volume	0.530	
Mean (Mm^3) Simulated Volume	0.572	
% Difference Between Mean (Mm^3)	-7.862	0.000
T Statistic For Comparing Means	-3.276	
Variance Observed Volume	0.680	
Variance Simulated Volume	1.332	
% Difference Between Variance	-95.982	0.000
Standard Deviation Observed Volume	0.825	
Standard Deviation Simulated Volume	1.154	
% Difference Between Standard Deviation	-39.993	0.000
Standard Error Observed Volume	0.007	
Standard Error Simulated Volume	0.010	
% Difference Between Standard Error	-39.993	0.000

Figure 5.1 *Time Series Analysis – Comparative Statistics* window

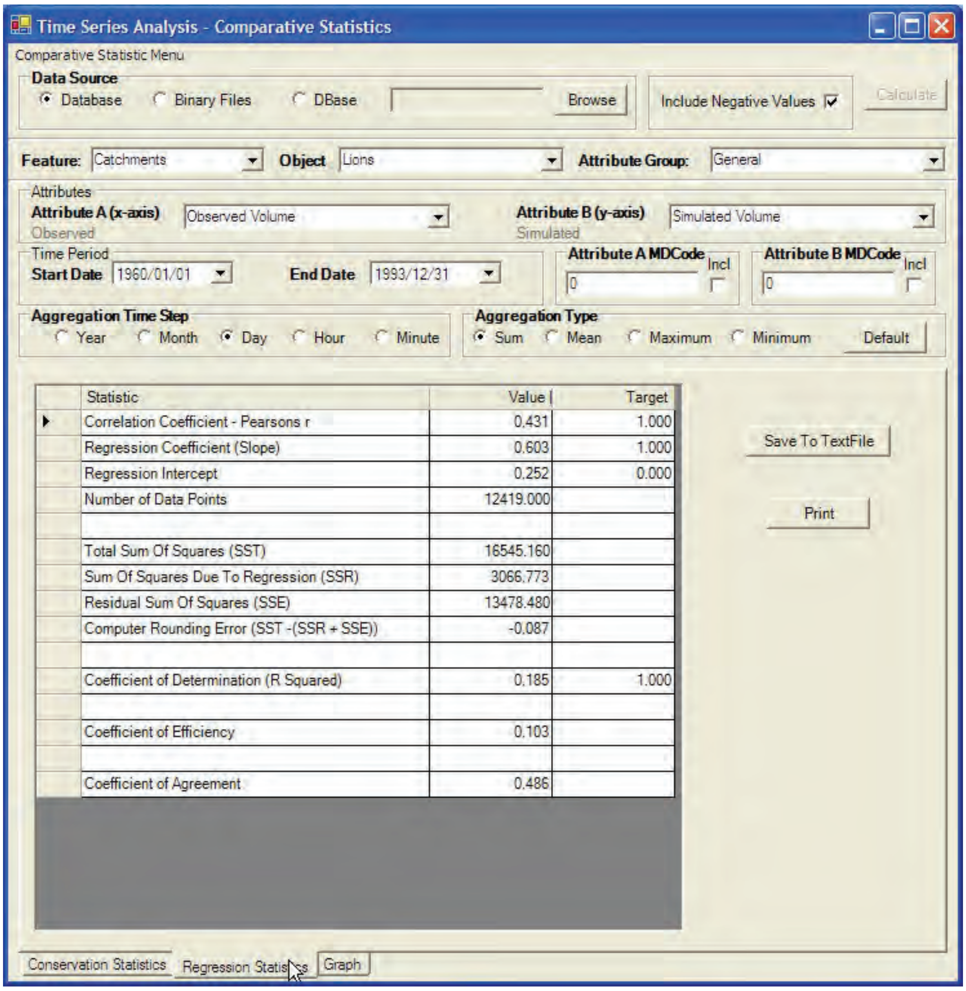


Figure 5.2 Example of the *Regression Statistics* tab on the *Time Series Analysis – Comparative Statistics* window

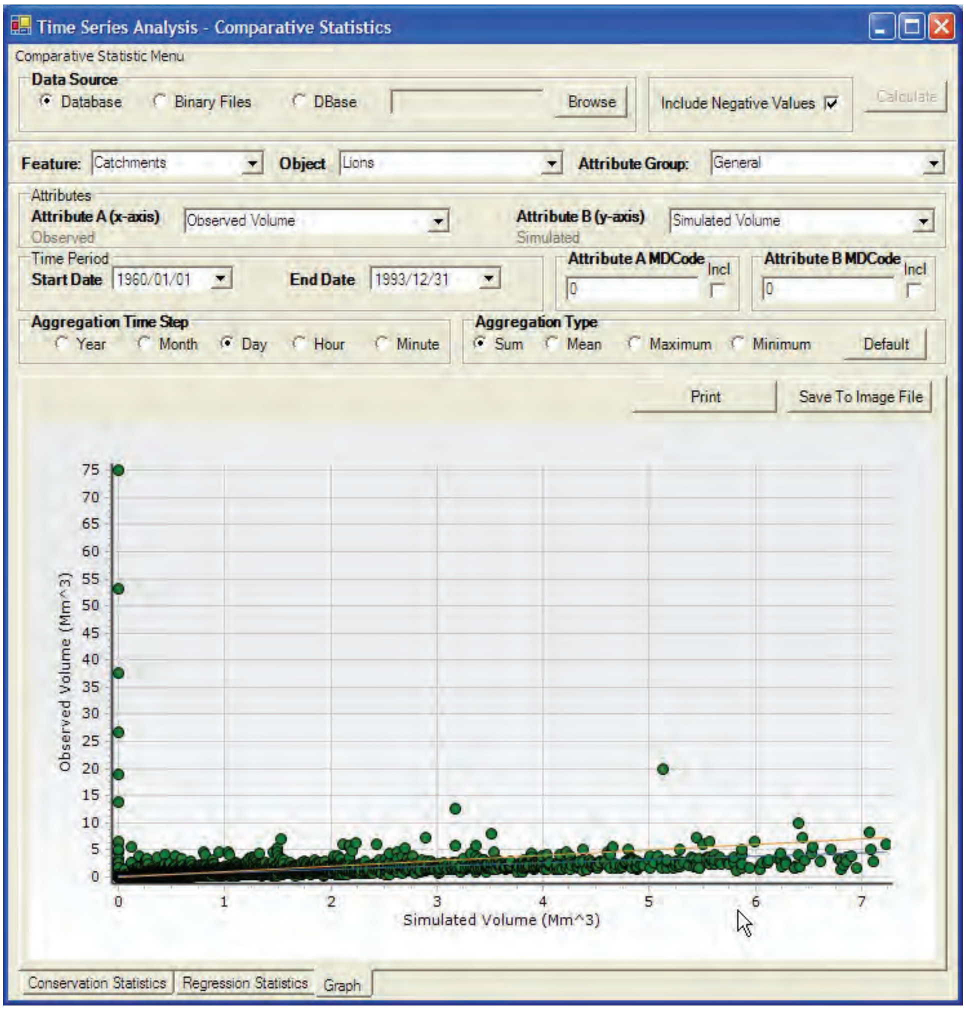


Figure 5.3 Example of the *Scatter Plot* tab on the *Time Series Analysis – Comparative Statistics* window

6. FREQUENCY ANALYSIS

The purpose of the *Time Series Analysis – Frequency Analysis* tool is to enable monthly, partial and annual frequency analyses to be performed on a selected time series and the results displayed as a table of values or a set of graphs. An example of the *Time Series Analysis – Frequency Analysis* window is shown in

Figure 6.1. This window consists of two main sections, the time series selection and options panel at the top, and the frequency analysis results *Table* and *Graph* tabbed pages at the bottom. The procedure to perform a frequency analysis is described as follows:

- Select a data source and a time series to be analysed , as described in Section 2.1.
- Select an aggregation time step and aggregation option type relevant to the selected time series. Further details about these choices are described in Section 2.2.
- Select the start month for the hydrological year. The default is October.
- Set upper and lower threshold values to exclude values in the time series that fall outside these thresholds.
- Specify a missing data value so that data points less than the missing data value are not included in the analysis.
- Specify whether an exceedance or a non-exceedance probability type of frequency analysis is to be performed.
- Select which months of the year not to be included in a partial analysis. By default all the months are included in the partial analysis.
- Once these options have been set, a frequency analysis can be performed by clicking on the *Calculate* button.

The results may be viewed in table format within the *Table* tab which is shown in
Figure 6.1 **or plotted on a graph within the *Graph* tab as shown in**

- **Figure 6.2**. In the *Graph* tab there are options to view the monthly frequency analysis graph, the partial frequency analysis graph and the annual frequency analysis graph. In the case of the monthly frequency analysis graph, months can be excluded from the graph by un-checking the month.
- The results may be printed or saved to a text file. In the case of the *Graph* tab, the graph can be printed or saved to an image file.
- This setup for the analysis can be saved to an ATF as described in Section 2.3.2 and Section 2.3.3.

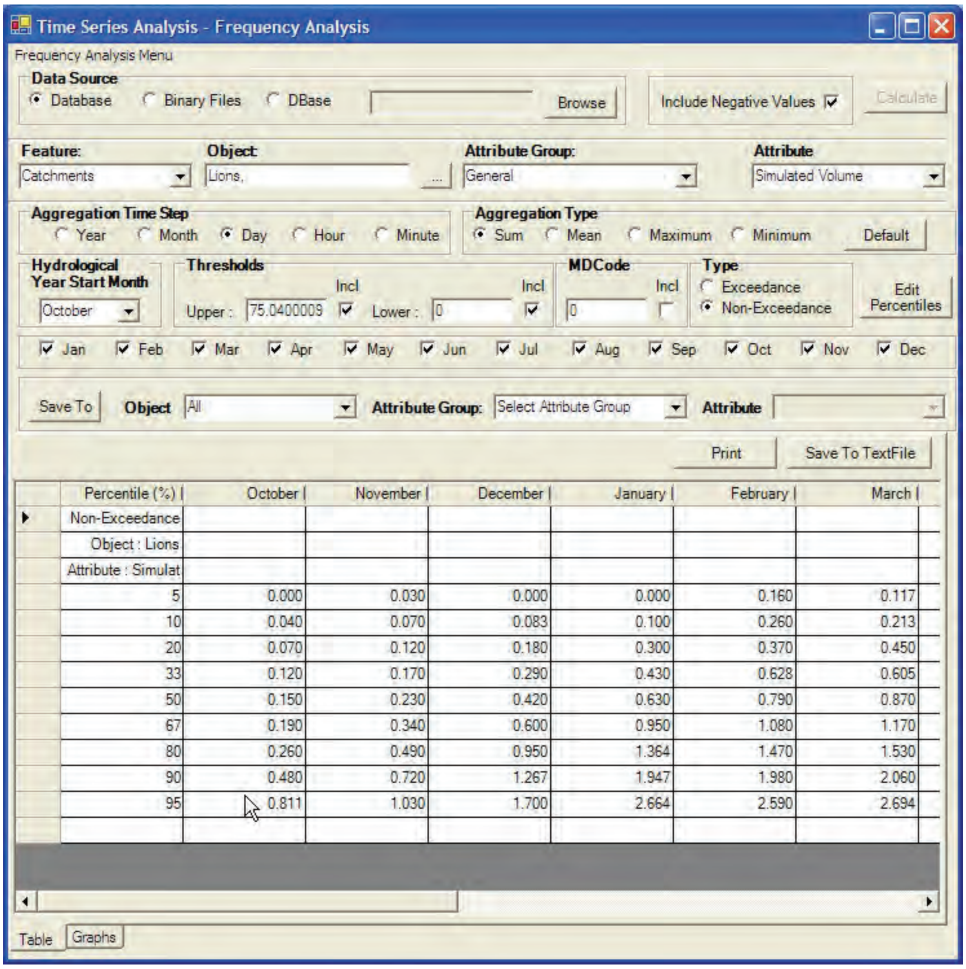


Figure 6.1 Example of the *Time Series Analysis – Frequency* Analysis window

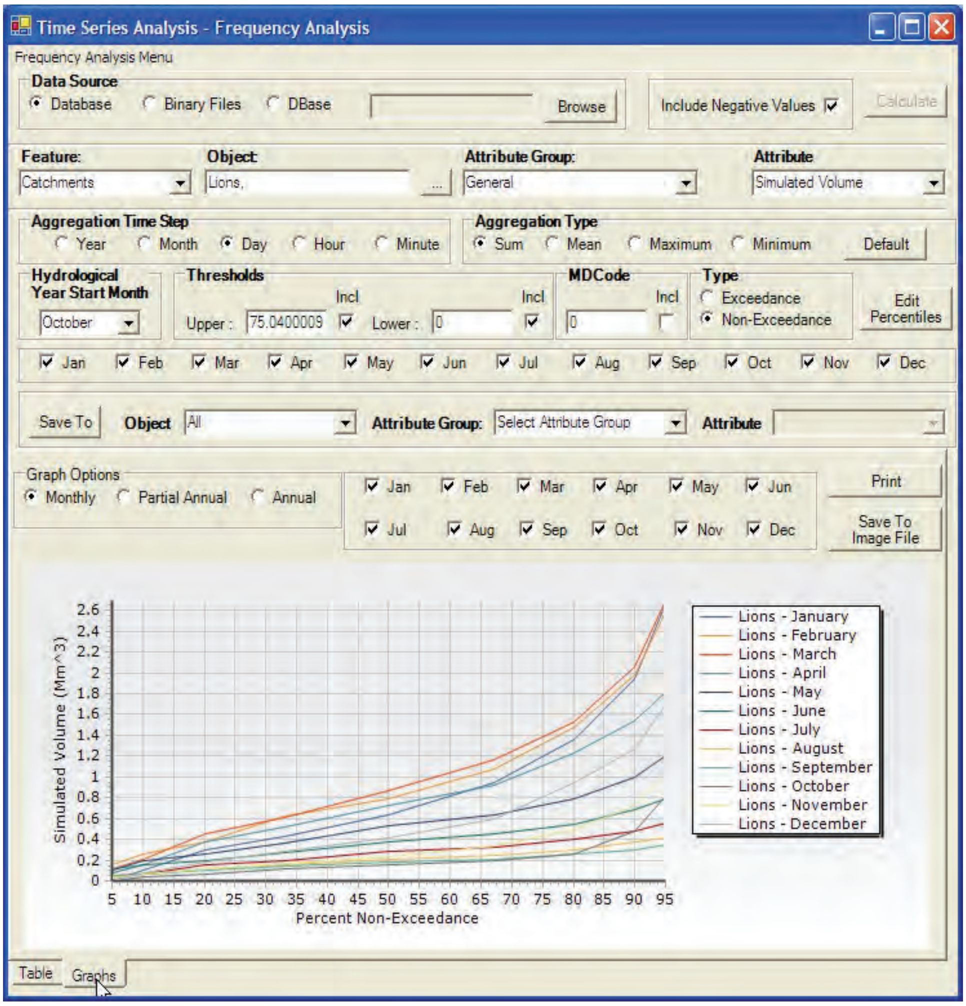


Figure 6.2 Example of the Graphs tab on the *Time Series Analysis – Frequency* Analysis window

7. EXTREME VALUE DISTRIBUTIONS

The *Time Series Analysis – Extreme Value Distributions* tool calculates the annual maximum series of a time series attribute. The annual maximum series is then used to work out the Normal, Log-Normal, Gumbel and Log-Pearson Type 3 distributions. An example of the *Time Series Analysis – Extreme Value Distributions* window is shown in
Figure 7.1. This window consists of two main sections, the time series selection and options panel at the top, and the extreme value distribution analysis results section at the bottom. The results section contains *Annual Maximum Series*, *Statistics*, *Log Normal Distributions*, *Normal Distributions*, *Gumbel Distributions*, *Log Pearson 3 Distributions*, and *Graph* tabbed pages. The procedure to perform an extreme value distribution analysis is described as follows:

- Select a data source and a time series to be analysed, as described in Section 2.1
- Select an aggregation time step and aggregation option type relevant to the selected time series. Further details about these choices are described in Section 2.2.
- Select the start month for the hydrological year. The default is October.
- Specify a missing data value so that data points less than the missing data value are not included in the analysis.
- Once these options have been set, the extreme value distributions can be calculated by clicking on the *Calculate* button.

The results are then displayed in the tabbed pages on the bottom of the window. An example of the *Annual Maximum Series* tab is shown in
Figure 7.1**. An example of the *Statistics* tab is shown in**
Figure 7.2**. An example of the *Log Normal Distributions* tab is shown in**
Figure 7.3**. An example of the *Normal Distributions* tab is shown in**
Figure 7.4**. An example of the *Gumbel Distributions* tab is shown in**
Figure 7.5**. An example of the *Log Pearson 3 Distributions* tab is shown in**
Figure 7.6**. An example of the *Graph* tab is shown in**

- **Figure 7.7**. All the results that are displayed in a table can be printed to a file and data saved to a text file. The graph of the distributions can be printed or saved to an image.
- This setup for the analysis can be saved to an ATF as described in Section 2.3.2 and Section 2.3.3.

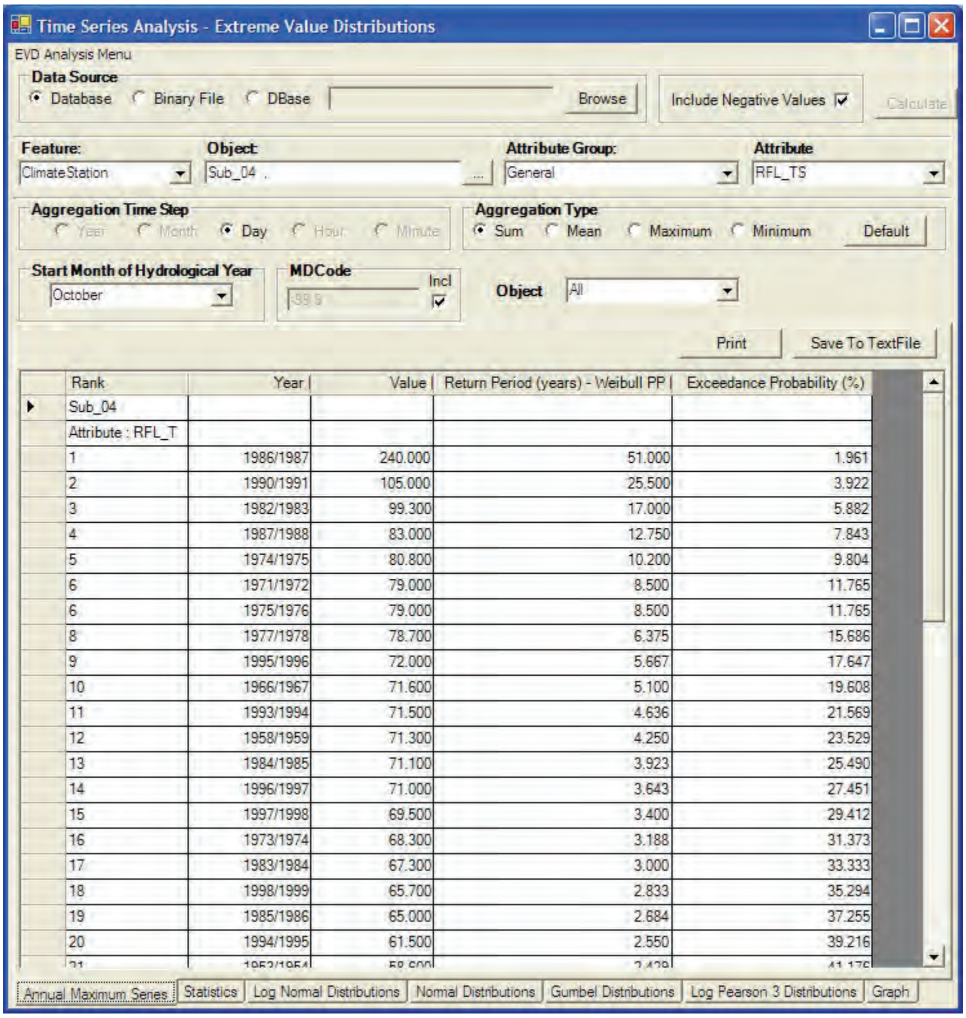


Figure 7.1 Example of the *Time Series Analysis - Extreme Value Distributions* analysis window

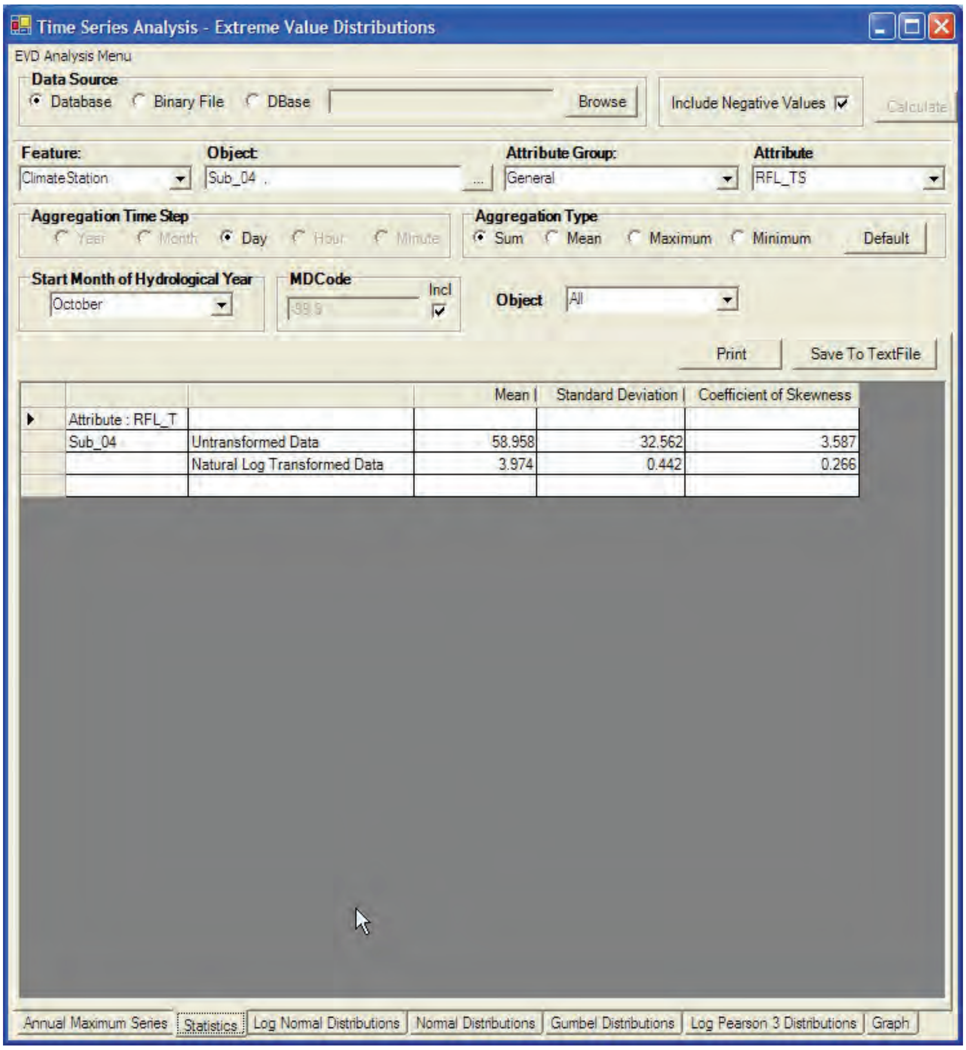


Figure 7.2 Example of the *Time Series Analysis - Extreme Value Distributions* analysis window with *Statistics* tab page selected

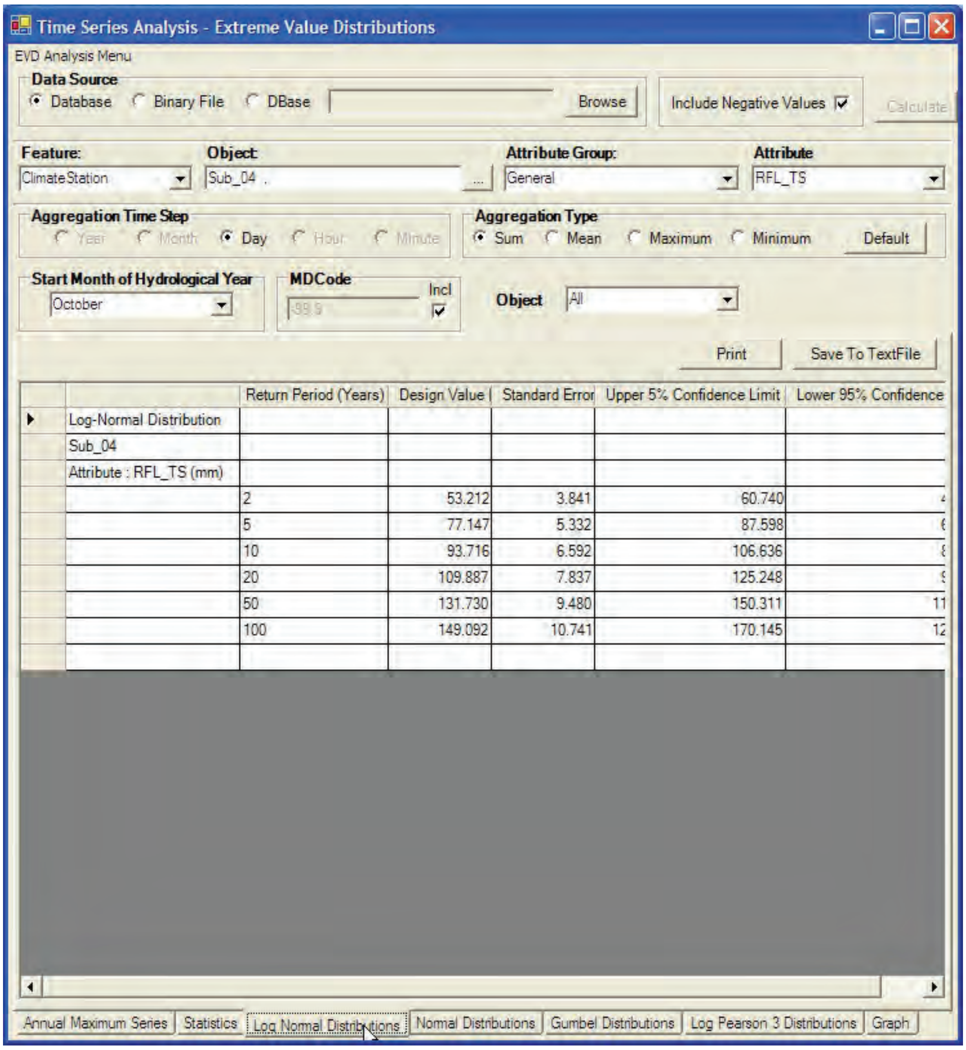


Figure 7.3 Example of the *Time Series Analysis - Extreme Value Distributions* analysis window with the *Log Normal Distributions* tab page selected

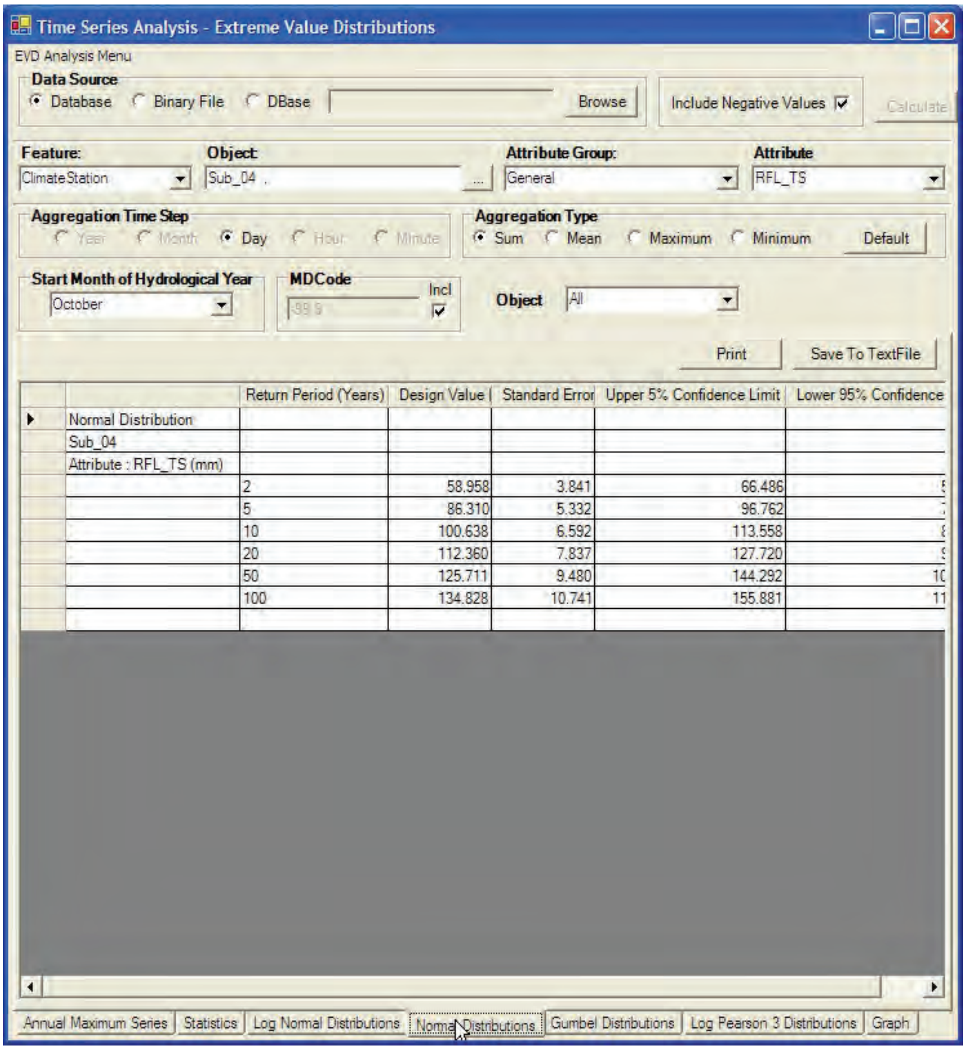


Figure 7.4 Example of the *Time Series Analysis - Extreme Value Distribution* Analysis window with the *Normal Distributions* tab page selected.

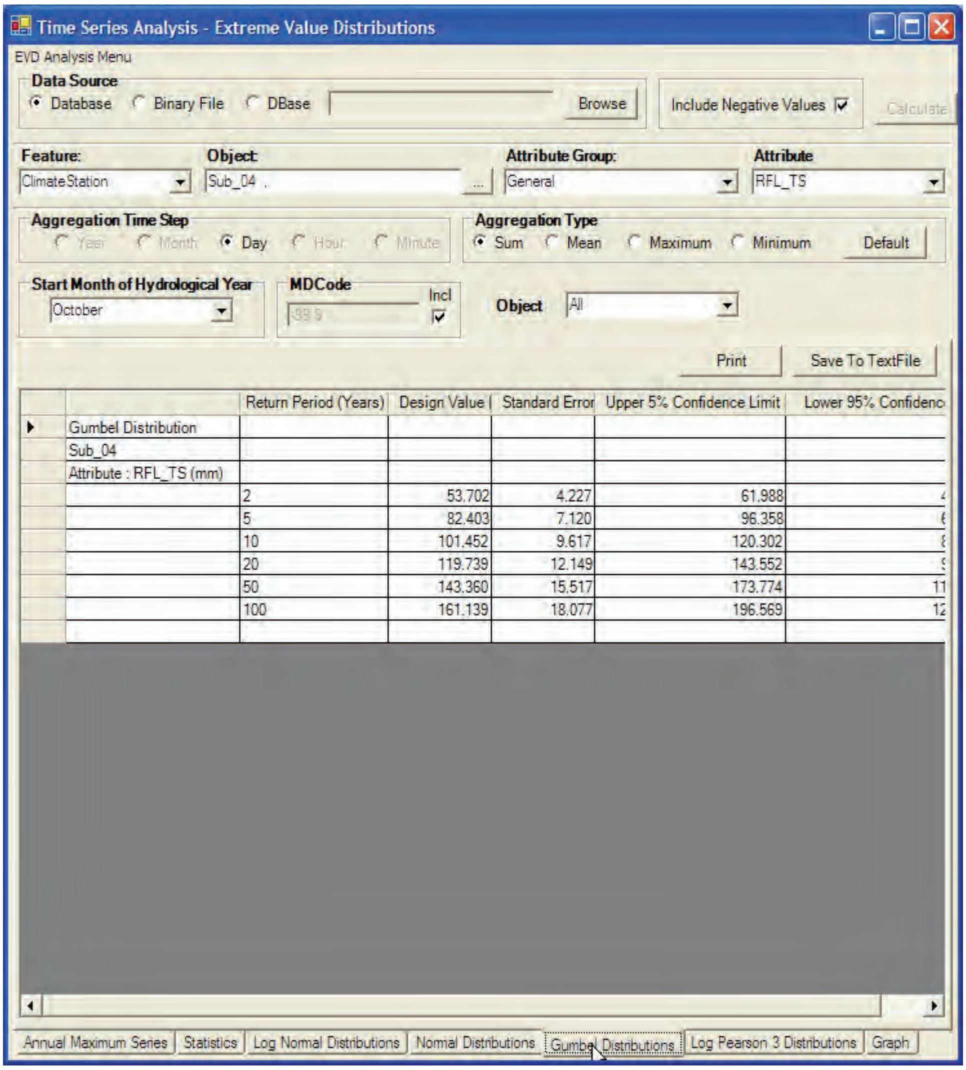


Figure 7.5 Example of the *Time Series Analysis - Extreme Value Distribution* Analysis window with the *Gumbel Distributions* tab page selected

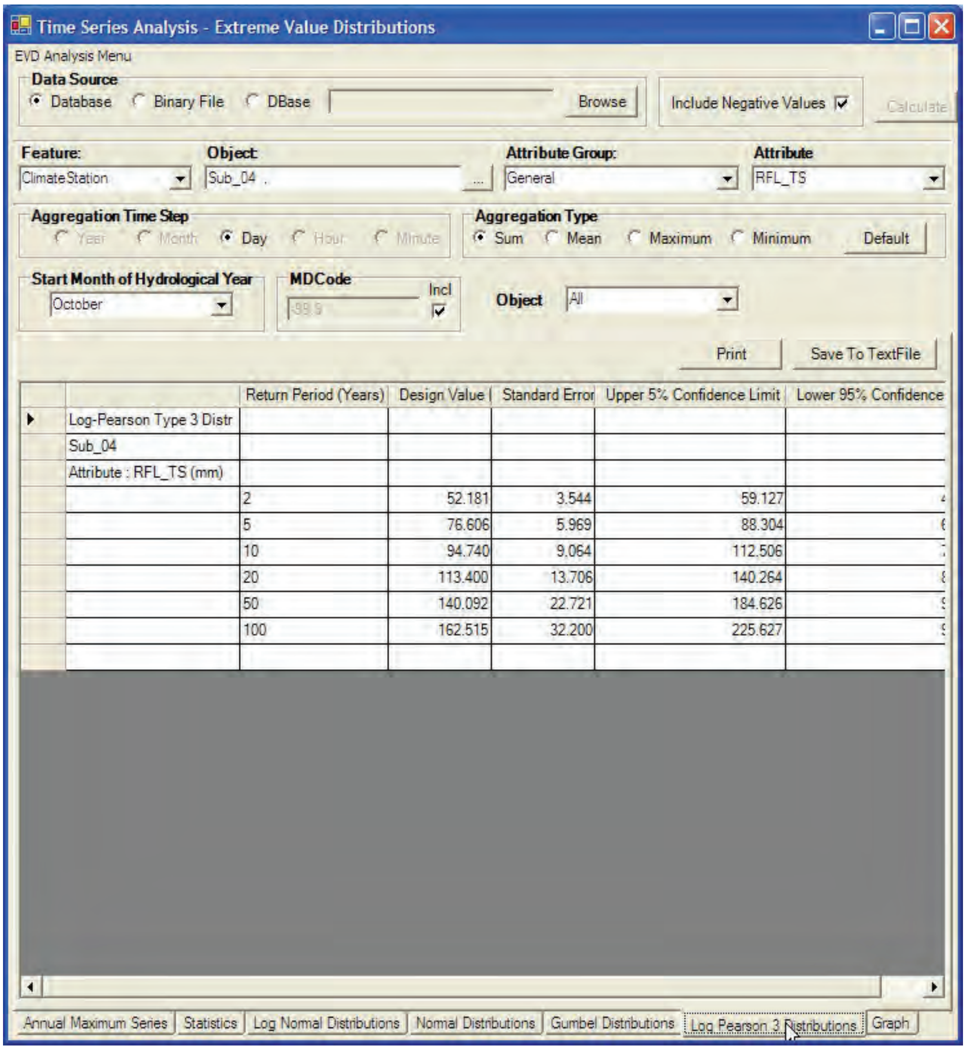


Figure 7.6 Example of the *T/S Analysis - Extreme Value Distribution* Analysis window with the *Log Pearson 3 Distributions* tab page selected

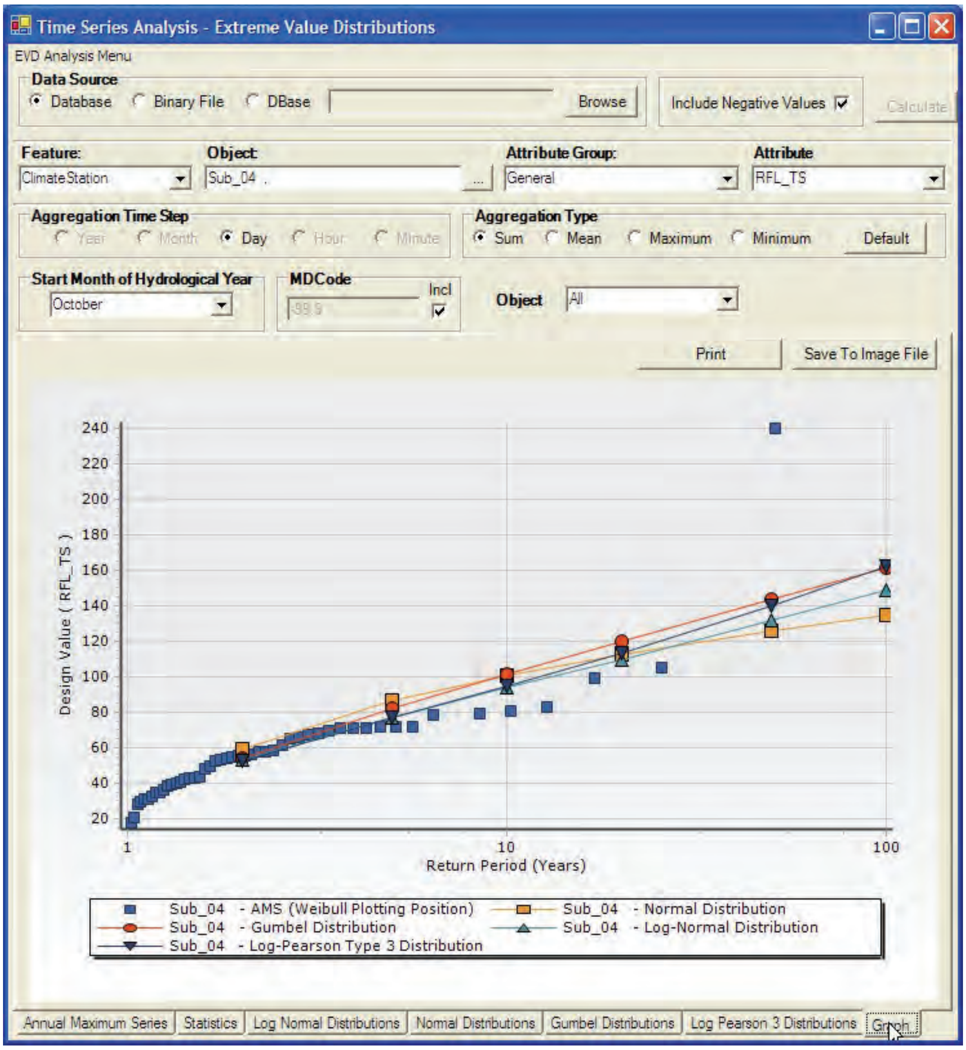


Figure 7.7 Example of the *T/S Analysis - Extreme Value Distribution* analysis window with the *Graph* tab page selected

8. RUN LENGTH ANALYSIS

The *Time Series Analysis – Run Length Analysis* tool calculates the lengths of consecutive days that a time series data set is above a threshold value or below a threshold value. In this tool up to six threshold values can be specified. An example of the *Time Series Analysis – Run Length Analysis* window is shown in

Figure 7.1. This window consists of two main sections, the time series selection and options panel at the top, and the run length analysis results in the *Graph* tab at the bottom. The procedure to perform a run length analysis is described as follows:

- Select a data source and a time series to be analysed, as described in Section 2.1.
- Specify a missing data value so that data points less than the missing data value are not included in the analysis.
- There are controls to specify up to six threshold values. Specify one or more threshold values to be used in the analysis.
- Once these options have been set, the run length analysis can be performed by clicking on the *Calculate* button.
- The tool works out two separate set of results, the runs that are above a threshold value and the runs that are below a threshold value. These separate results are plotted in separate graphs in the *Graph* tab page as shown in **Figure 8.1**. Right clicking on each graph brings up a context menu with the option to show/hide a legend, an option to print the graph and an option to export a graph to an image file.
- There is a dropdown control that allows the display of the results for all/individual objects selected as shown in **Figure 8.1**.
- This setup for the analysis can be saved to an ATF as described in Section 2.3.2 and Section 2.3.3.

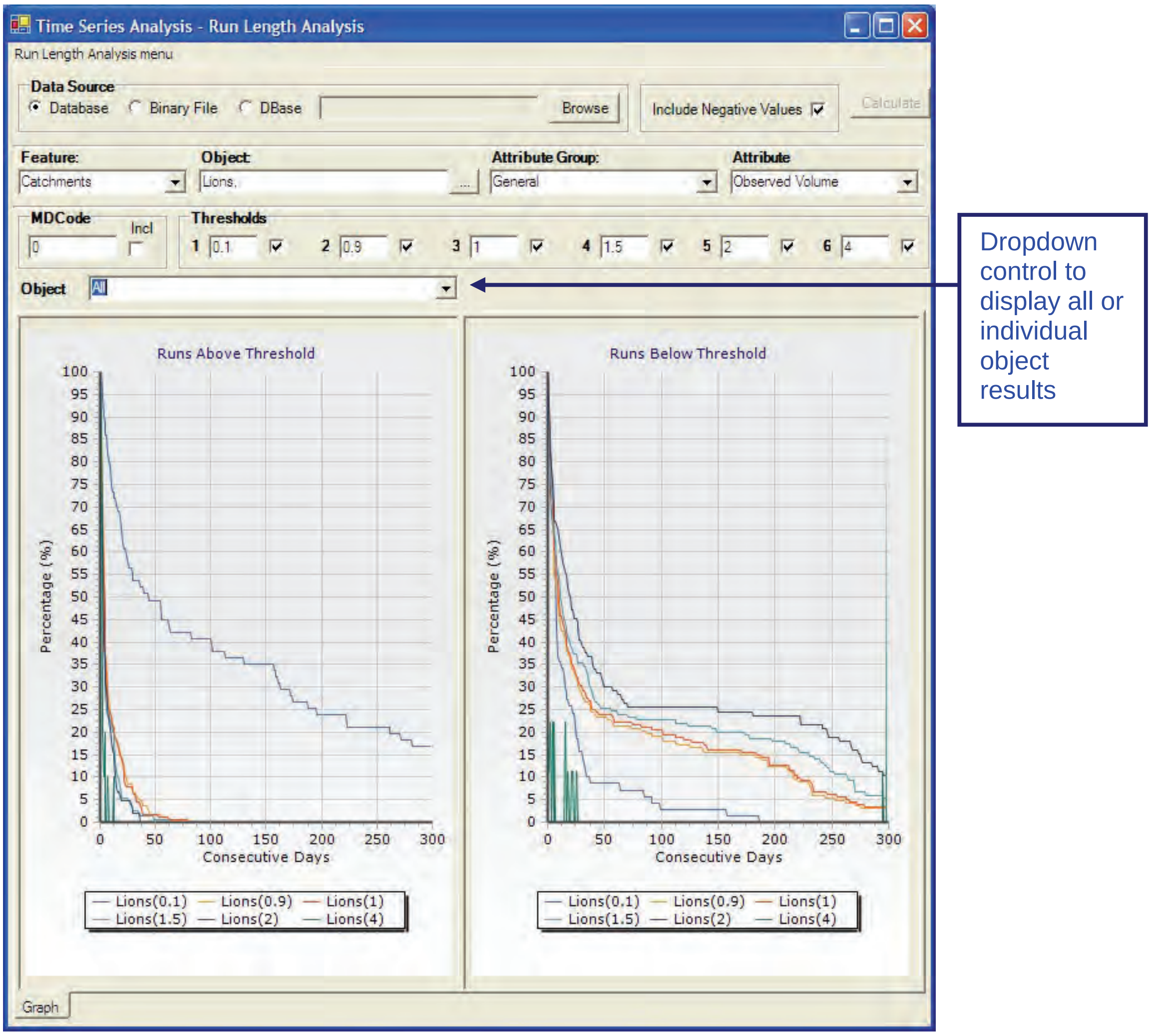


Figure 8.1 Example of the *Time Series Analysis - Run Length Analysis* window

9. HIGH/LOW PERIOD ANALYSIS

The *Time Series Analysis – High/Low Period* tool searches through a time series and finds the time period with the highest or lowest mean value for the given time period length. An example of the *High/Low Period* window is shown in

Figure 9.1. This window consists of two main sections, the time series selection and options panel at the top, and the high/low period results section at the bottom. The results section contains a *Data* tabbed page. The procedure to perform a high/low period analysis is described as follows:

- Select a data source and a time series to be analysed, as described in Section 2.1
- Select an aggregation time step and aggregation option type relevant to the selected time series. Further details about these choices are described in 2.2.
- Select the start month for the hydrological year. The default is October.
- Specify a missing data value so that data points less than the missing data value are not included in the analysis.
- Specify whether the highest or lowest mean value for the specified period length needs to be found in the *Period Type* option control. Specify period length to be used in the search in the *Period Length* field. The time step for the period length is the *Aggregation Time Step* selected.
- Once these options have been set, the high/low period calculation can be performed out by clicking on the *Calculate* button.
- The highest or lowest mean found is displayed together with the start and end date for that period within the *Data* tab at the bottom of the window. The data can be printed or saved to a text file.

There is a dropdown control that allows the display of the results for all/individual objects selected as shown in

- **Figure 9.1**.
- This setup for the analysis can be saved to an ATF as described in Section 2.3.2 and Section 2.3.3.

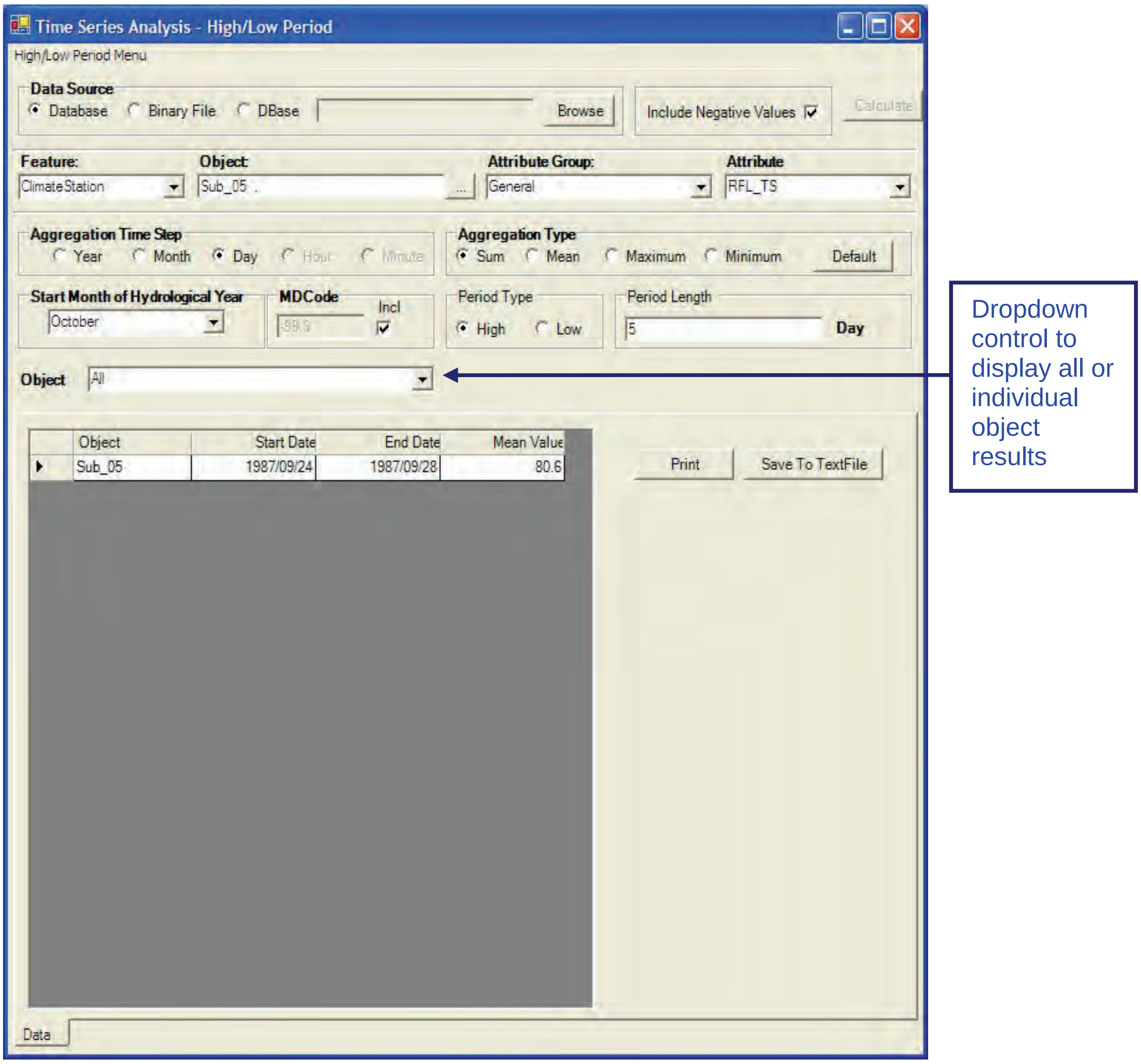


Figure 9.1 Example of the *Time Series Analysis - High/Low Period* Analysis window

10. TRANSFORMATIONS

The *Time Series Analysis – Transformation* tool transforms time series values for one or more objects in a feature. Only time series attributes in a SPATSIM-HDSF database data source may be transformed. The *Time Series Analysis – Transformation* window consists of two tabbed pages. The first tabbed page is the *General* tab page. The second tabbed page is the *Equation* tabbed page. An example of the *Transformation* window with *General* tab page selected is shown in
Figure 10.1**. An example of the *Transformation* window with *Equation* tab page selected is shown in**
Figure 10.2.

Use the following procedure on the *General* tabbed page:

- Select a data source and a time series to be analysed, as described in Section 2.1.
- Specify a missing data value so that data points less than the missing data value are not included in the transformation.
- Select a transformation operation within the *Operations* area on the window.
- Set an accumulation period if relevant.
- Set the factor (Y) value if relevant.
- Select a second time series (TS2) attribute from the list provided if relevant.
- Select a time series attribute from the list provided, to which the transformed time series is to be saved.
- Transform and save the selected time series by clicking the *Transform and Save* button.
- View and edit the new time series attribute by clicking the *View Saved Data* button. If more than one object has been selected, prior to clicking on the *View Saved Data* button then one object needs to be selected.

Use the following procedure on the *Equation* tabbed page:

- Select a data source and a time series to be analysed, as described in Section 2.1.
- Select a transformation equation type in the *Equation Type* section.
- Set a threshold for the X value.
- Set the equation A, B and C coefficients to be used for time series values below and above the specified threshold value in the *Coefficients* section.
- Select a time series attribute from the list provided, to which the transformed time series is to be saved.
- Transform and save the selected time series by clicking the *Transform and Save* button.

- View and edit the properties of the new time series attribute by clicking the *View Saved Data* button. If more than one object has been selected, prior to clicking on the *View Saved Data* button then one object needs to be selected.

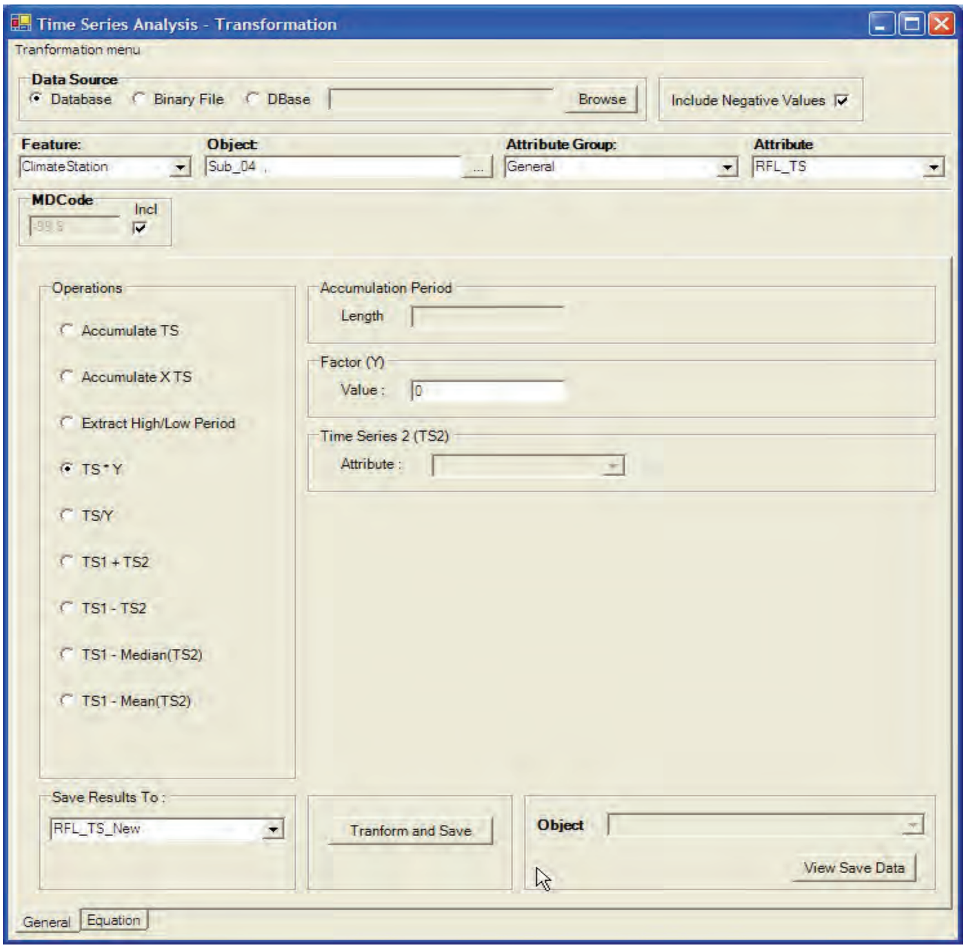


Figure 10.1 Example of the *Time Series Analysis - Transformation* window with the *General* tabbed page selected

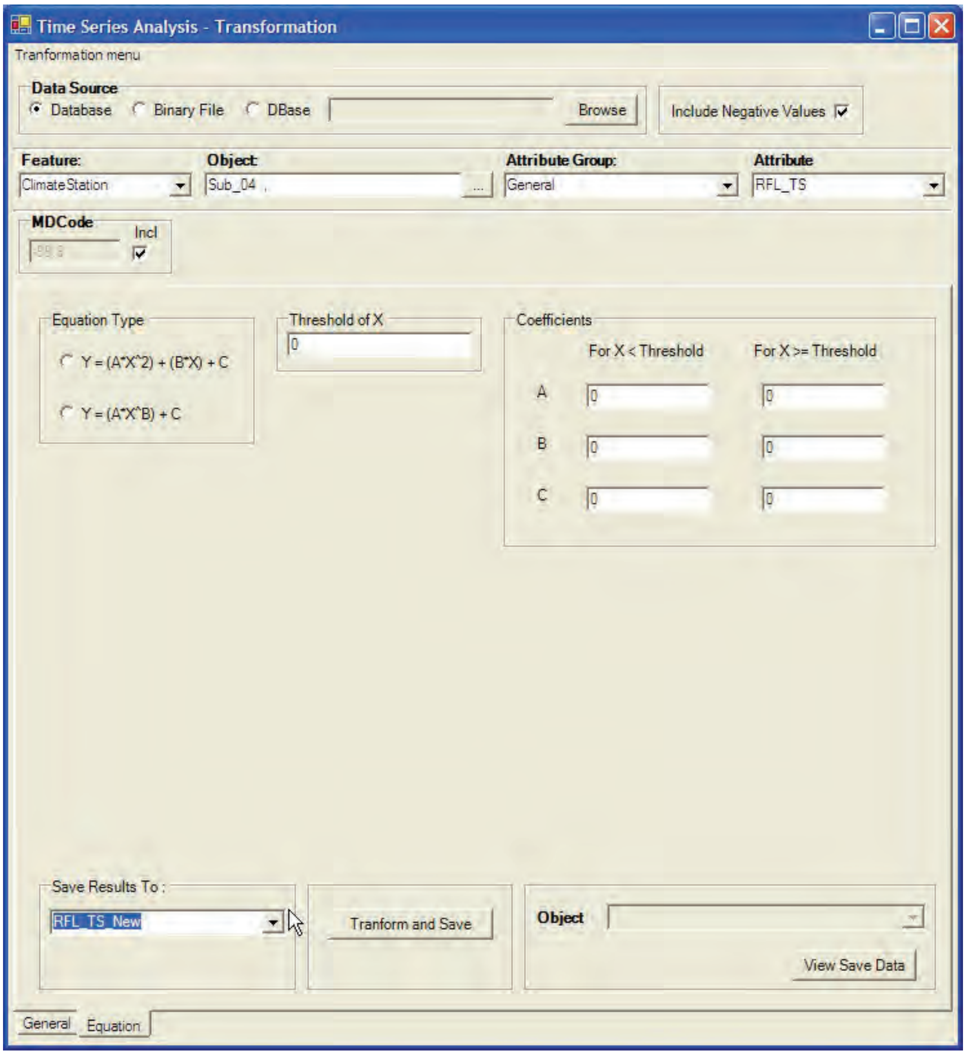


Figure 10.2 Example of the *Time Series Analysis - Transformation* window with the *Equation* tabbed page selected