Catchment Modelling Parameter Library: Development and Population

Nick Marsh[1,2], Sunil Tennakoon[1,2], Sylvian Arene[1,3] and Banti Fentie[1,4]

1 National Action Plan for Salinity and Water Quality, 80 Meiers Road, Indooroopilly QLD 4068
www.wqonline.info/
2 Queensland Environmental Protection Agency, (postal address as above) nick.marsh@epa.qld.gov.au ,
sunil.tennakoon@epa.qld.gov.au
3 Griffith University, Nathan Campus, 170 Kessels Road, Nathan QLD 4111. s.arene@griffith.edu.au
4 Department of Natural Resources, Mines and Water, Block B, 80 Meiers Road, Indooroopilly QLD 4068.
Banti.Fentie@nrm.qld.gov.au

Abstract:
Catchment process models, which predict water quantity and quality, are commonly used to support natural resource management planning. Process based modelling applications usually require the 'art' of modelling to be applied to develop appropriate model parameter sets through optimisation routines, existing data, expert opinion and historic precedent. These parameter sets can form the key scientific contribution of a model application activity. However, the parameter sets are poorly reported and as a consequence they are undervalued. This paper describes a software tool, the 'Parameter Library' designed for storing, accessing and sharing parameter sets. The Parameter Library provides a collective database to archive parameter values, and more importantly the science, data and expert opinion behind the selection of appropriate model parameters. The Parameter Library database is intended to be a point of reference for modellers so that old modelling runs can be revisited, new model development can benefit from what has gone before and those new to modelling can benefit from the wealth of experience that has gone into model parameter selection for previous models. The model Parameter Library is targeted primarily at catchment modellers but there is broader value simply as an archiving tool. The prototype has been designed for "SedNet" model parameters and would require some minor software development to automate its interaction with packages other than "SedNet".

Key Words:

Model, Parameter, SedNet, Water quality, Catchment

1. INTRODUCTION

During the last two decades, computer-based mathematical models of catchment hydrology have been widely used for a variety of applications including hydrologic forecasting, hydrologic design, water resources management and environmental applications. Many of these models are based on mathematical descriptions of the catchment processes that transform natural systems such as rainfall and landscape into responses such as runoff and pollutant movements. The model developer must specify the model parameters before the model is able to properly simulate the catchment performance. The values for model parameters can be determined with a high degree of precision, if the processes controlling the system are well understood. However, in hydrology, the physical processes of concern are complex and often not well understood and suitable data for model calibration do not exist. Further, properties of landscape and climatic conditions are highly variable in space, and not easily measurable at the spatial and temporal scales required by the applied models. Considering these spatial and temporal variations, model parameters must be estimated for each specific application of the model for accurate predictions.

A number of approaches are used for estimating model parameter values. One approach is estimating model parameters by relying on empirical relationships that relate parameters to measurable characteristics (soil and vegetation properties, catchment geomorphology, topographical features etc) of the catchment (Carlile et al 2004). Another approach is to adjust existing model parameter values (model calibration approach), so that the model input-output response closely matches the observed input-output response of the catchment for some historical period for which data have been collected (Bardossy, 2006). Past experience has shown the profound complexity of estimating values for hydrologic model parameters, either by the local estimation or model calibration approaches (Parajka et al 2005). As all models are approximations of the real world, model equations and associated parameters are formulated representations, which are not directly related to measurable catchment characteristics. Furthermore, there are a variety of errors in the model structure and uncertainties in the data used for parameter estimation, which introduce considerable inaccuracy into model outputs.

These factors have made it difficult to develop reliable procedures for model parameter estimation, and to provide suitable estimates of uncertainties in the resulting model predictions. As a result parameter sets are necessarily developed through an expert assessment of a combination of numerical calibration, pragmatic decisions and historic precedent. This expert assessment or ‘art’ of parameterising models is acquired by expert modellers over several years. The apprenticeship of new modellers and demystification of modelling can be greatly enhanced by creating a modelling knowledge base. A modelling knowledge base should provide a point of reference for new modellers, a method of documenting existing model runs and provide a mechanism to highlight deficiencies in our modelling knowledge to more clearly direct future research activities.

2. SYSTEM DESIGN

The Parameter Library has been designed to capture, store and search historical model parameter values and relevant metadata. This software tool contains a model parameter database, a knowledgebase, search engine, project or parameter related information and a comprehensive help system. The basic components of the Parameter Library software tool are shown in Figure 1.

The targeted end users for this model parameter library are people who need to develop local or regional catchment models for managing and conserving water quality. These users include research institutes, environmental groups, state and local governments, regional natural resource management organisations and industry groups. Having focused on end users requirements and capabilities, the interface was developed for easy operation by selecting available options or simply answering questions appearing on the screen.

2.1 User Interface

The Parameter Library interface is a clean windows style interface with navigation via a left tree-view and menu. All commonly accessed items are available through the tree view. Items accessed less frequently such as display options and options for adding new parameters or computer models are accessed via the menu screens.

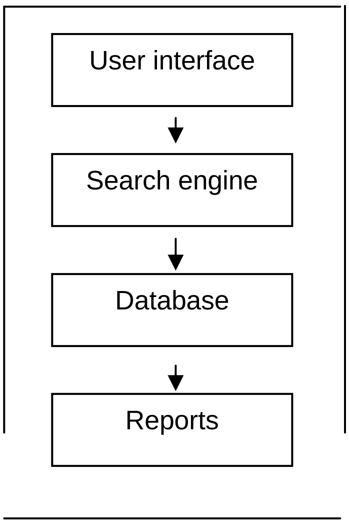


Figure 1. Basic structure of the hydrology model parameter library

The interface was designed to be compatible (look and feel) with other eWater Cooperative Research Centre toolkit (www.toolkit.net.au) software tools. The interface was designed to run the software with minimum training requirements and the tree-view located at the left hand side of the screen provides easy navigation (Figure 2). A standard HTML help system has been built-in to the system to assist users, explaining every step in running the software.

2.2 Database Structure

The key element of the Parameter Library is a relational database. The database has been designed to provide a sensible and flexible basis for entering parameter sets that may be suitable for a large range of modelling programs. The database is made up of three relational tables.

The first table contains project based information and allows parameter sets to be allocated to a person, region and modelling application. The basis for the project table is that for archiving, information or parameter sets are often stored on a project basis. Projects are also location specific, hence parameter values for a given project can also be used to imply a geographical application for a parameter value.

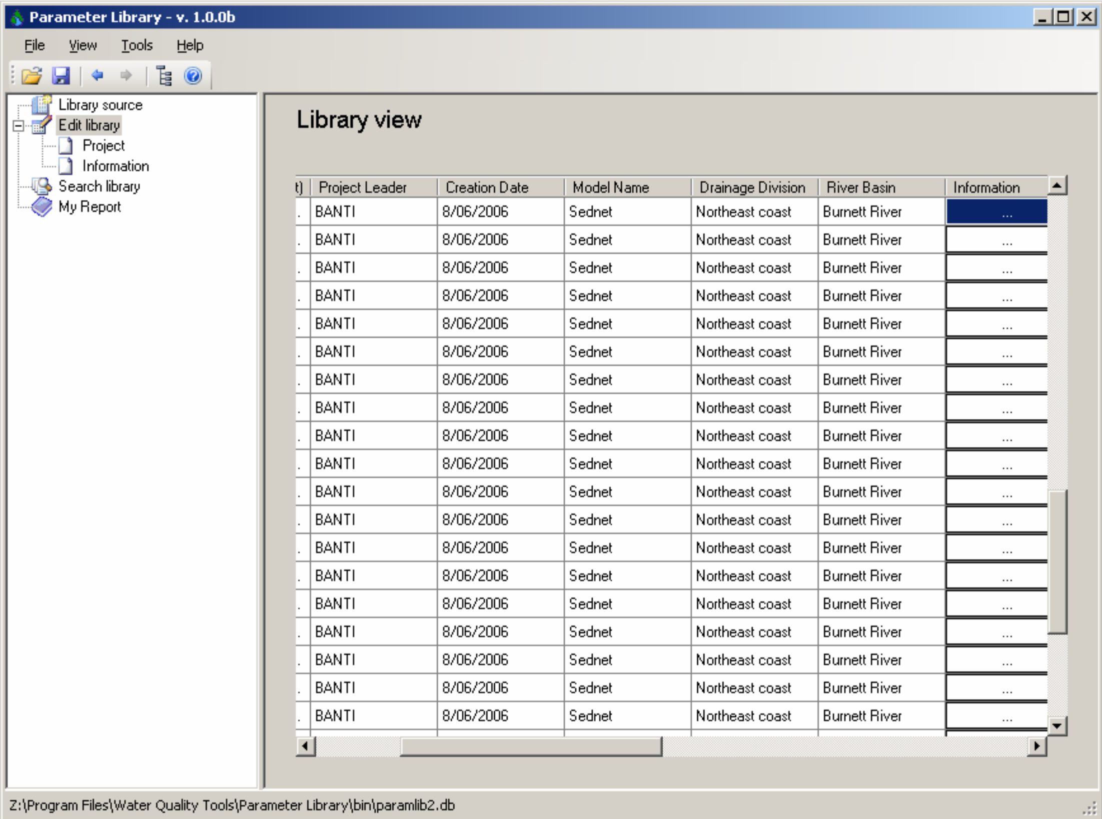


Figure 2. Parameter library user interface (data view)

The second table is the parameter table, which contains all the details of specific parameters, their values, descriptions, default and modified values and any relevant free text the user wishes to store. This table is the key component of the database and has been designed to be expandable, allowing users to build on the table by adding new parameter types at run time.

The third key table is the 'information' table. The information table is for storing any ancillary information presented as either files or web links. Example information would be example photographs of sites, project configuration files, project reports or presentations. Any ancillary information can be associated with any project or any parameter.

This configuration of tables within the database allows project information to be associated with any parameters. Ancillary information can be associated with any parameter or project information. For example, a photograph of gully erosion in the Fitzroy catchment may be associated with a given modelling project, but may also be a good demonstration of what the 'gully cross sectional area' parameter is used to predict, hence it may be associated with this single parameter across all projects.

2.3. Search Engine and Reporting

A key element to making a modelling knowledgebase useful is to ensure that the database is easy and efficient to search. Those search results need to be able to be sorted, stored and modified for producing useful reports. The search engine in the parameter library is a clean and simple search engine that allows searching by any combination of keyword, model software name, parameter name, project name, drainage division or creation date. In this way users have a relatively comprehensive range of methods by which to search the database.

On the completion of the searching process, a table of results is presented. The user can select records of interest from the search results, which are then added to a reporting table for subsequent investigation or saving. The reporting table can be used to save the interesting records from several searches.

3. SOFTWARE DEVELOPMENT

The Parameter Library software was written in C# language using microsoft .NET framework 2.0 and it is required to install Microsoft .NET Framework Version 2.0 Redistributable Package (x86) to install and run this software. The .NET framework 2 allows creating applications within the TIME (The Invisible Modelling Environment) (Rahman et al 2003) making the codes reusable in other eWater CRC software projects. The "nHibernate" (www.hibernate.org) object-relational mapping solution for .NET was used for database interactions. This object oriented programming approach gives an advantage of database type independency and the same data management procedures can be applied for both local and online databases. The choice for the local database has been SQLite, which can be easily embedded in any project and avoids any action or coding requirement from the user. The database structure has been developed to provide maximum flexibility for entering, storing and editing data records. Data records can be entered either manually or imported from model input files for "SedNet" (Wilkinson et al 2004).

4. USING THE LIBRARY

Three major options are available in the main menu: open a local library, create a new library and connect an online library. Editing, deleting, searching or linking resource information to the database can be performed on an opened library or a newly created library. The name of the working library is shown in the lower left hand side of the screen and all the records in the database can be viewed using the "Edit Library" option. The user can select required data fields for viewing, editing or reporting using the "Options" available in tools menu. The user can easily navigate the system using the tree-view in the left hand side of the user interface.

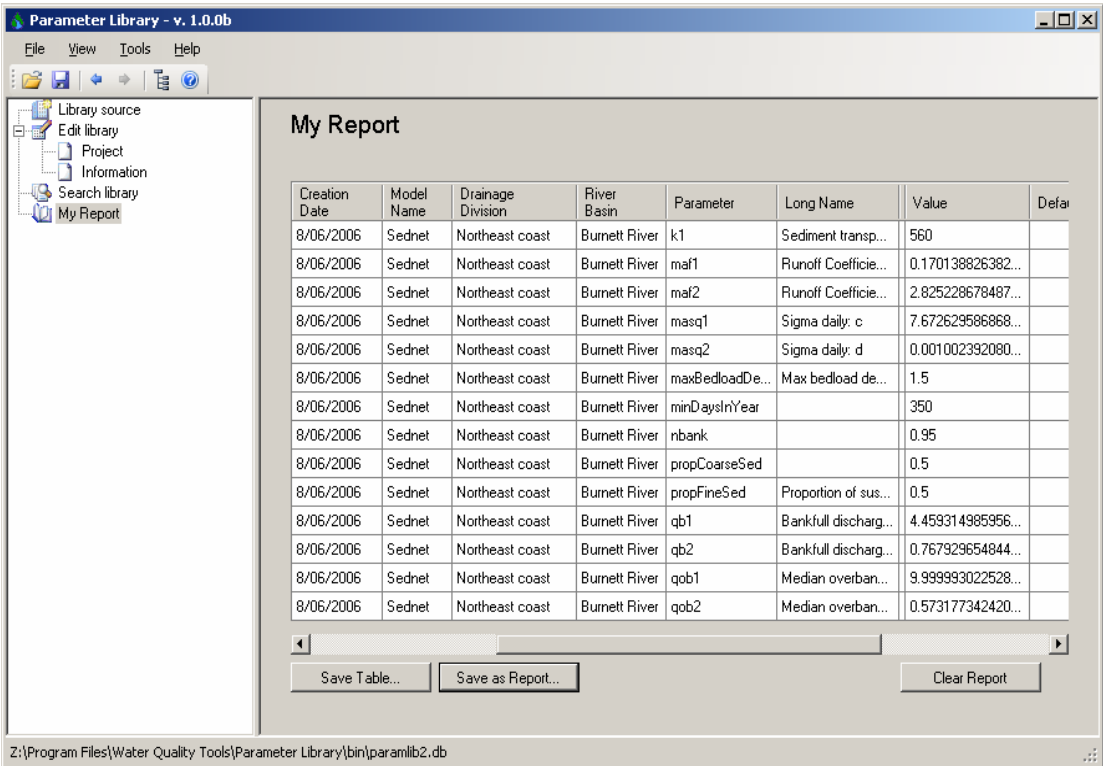
Create a new project: The basic information about the modelling project such as project title (name of the project), the name of the model, commencing date and the details of the location (drainage division and river basin) need to be manually entered or selected from the available list. A description of the project should also be included and the database has the capability to store supplementary project information as a list. This list can include project plans, reports, and papers and the library developer can attach these documents to the database depending on the availability and requirements. These supplementary information sources can be shared with other projects.

Parameter values and metadata: The actual parameter values for each of the parameters can be entered either manually or extracted from model input files. For manual entering, the user can select the parameter from the drop down menu and enter the actual parameter value you have used in a particular project. It is also important to record all the metadata available for these parameter values, which include the reasons for selecting that particular value, maximisation or optimisation procedures applied in deriving the value or describing the parameter calibration process. The local knowledge about the parameter value can also be stored in this field as text information. The system has been designed to enter and store supplementary/additional information related to model parameters including URL addresses.

Search library: A number of options are available for searching the database. A set of key words or truncated key words can be used to search parameter values. Model name, parameter name, model developer's name, time periods, location or project names can be used for searching the database. The user can generate a table of catchment, project or model developer specific parameter information, which can be used for generating location and time specific parameter values for a new modelling project.

Generate output: Using the search results, the user can generate a customised report by selecting required fields (Figure 3). The selected records can be exported to EXCEL file or saved as a project file, which can be used/modified later. It is also possible to save the searched result in a HTML format for printing or reporting purposes.

Adding or deleting of the detail of an entire model can be done using the "Model Editor" option available in the Tools menu. The "Parameter Editor" option allows entering new parameters, deleting parameters or editing the details of existing parameters. A few compulsory data fields must be entered when creating a new parameter and the data type can be specified using the drop down list available in the tool. A description of the parameter, which includes the parameter definition and the importance or sensitivity (Fentie et al 2005) of this parameter on model outputs, can be stored as text information.



Creation Date	Model Name	Drainage Division	River Basin	Parameter	Long Name	Value	Defa
8/06/2006	Sednet	Northeast coast	Burnett River	k1	Sediment transp...	560	
8/06/2006	Sednet	Northeast coast	Burnett River	maf1	Runoff Coefficie...	0.170138826382...	
8/06/2006	Sednet	Northeast coast	Burnett River	maf2	Runoff Coefficie...	2.825228678487...	
8/06/2006	Sednet	Northeast coast	Burnett River	masq1	Sigma daily: c	7.672629586868...	
8/06/2006	Sednet	Northeast coast	Burnett River	masq2	Sigma daily: d	0.001002392080...	
8/06/2006	Sednet	Northeast coast	Burnett River	maxBedloadDe...	Max bedload de...	1.5	
8/06/2006	Sednet	Northeast coast	Burnett River	minDaysInYear		350	
8/06/2006	Sednet	Northeast coast	Burnett River	nbank		0.95	
8/06/2006	Sednet	Northeast coast	Burnett River	propCoarseSed		0.5	
8/06/2006	Sednet	Northeast coast	Burnett River	propFineSed	Proportion of sus...	0.5	
8/06/2006	Sednet	Northeast coast	Burnett River	qb1	Bankfull discharg...	4.459314985956...	
8/06/2006	Sednet	Northeast coast	Burnett River	qb2	Bankfull discharg...	0.767929654844...	
8/06/2006	Sednet	Northeast coast	Burnett River	qob1	Median overban...	9.999993022528...	
8/06/2006	Sednet	Northeast coast	Burnett River	qob2	Median overban...	0.573177342420...	

Figure 3. A report generated from the parameter library software tool

5. FUTURE IMPROVEMENTS

The current version has a limited capacity in capturing and storing parameter values and this beta version is specifically designed for handling "SedNet" model parameters. However, new generation catchment models such as E2 (eWater CRC) have a wide variety of parameters, which varies between functional units within the same catchment or sub-catchment. Further comprehensive details of catchment model calibration techniques and expert knowledge for deriving local parameter could also be included. The facility for merging different libraries and an option for online library access could also be included.

6. CONCLUSIONS

The Parameter Library will be a valuable planning and operating tool for catchment modellers, project leaders and government agencies for archiving and sharing the collective modelling knowledgebase developed through catchment modelling exercises. Potential applications for the tool include preserving historical modelling information, deriving location and time specific model parameter values, collecting and storing project or parameter relevant information, accessing local catchment behaviour knowledge for parameter estimations and sharing modelling experience with a broader modelling community. This software tool will allow catchment modellers to revisit previous modelling exercises and evaluate improvements made in their predictions. This will also assist new or inexperienced catchment modellers to derive reasonable and reliable model parameters for better use of catchment models. Given, there is no formal techniques for capturing, preserving and reusing model parameter values in a broader scale, it remains to see how such a system will facilitate future catchment modelling activities and possible improvements in model predictions.

7. ACKNOWLEDGMENTS

The authors would like to acknowledge the contribution from Miss Deborah Gale at the University of Queensland for compiling the HTML help document. The parameter library software was developed with partial funding from the eWater CRC.

8. REFERENCES

Bardossy, A.B., Calibration of hydrological model parameters for ungauged catchments**.** Hydrology and Earth Systems Sciences Discussions, 3, 1105–1124, 2006.

Carlile, P.W., B.F.W. Croke, A.J. Jakeman, and B.C. Lees, Development of a semi-distributed catchment Hydrology model for simulation of land-use Change stream-flow and groundwater recharge Within the little river catchment, NSW. CRC for Landscape Environment and Mineral Exploration (LEME), Australia, Roach I.C. ed. Regolith. 54-56. 2004.

Duan, Q., S. Sorooshian, and V.K. Gupta, Optimal Use of the SCE-UA Global Optimization Method for Calibrating Watershed Models, Journal of Hydrology,158, 265-284. 1994.

Fentie, B., N. Marsh, and A. Steven, Sensitivity analysis of a catchment scale sediment generation and transport model. MODSIM 2005

International Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand, December 2005, 1140-1146. ISBN: 0-9758400-2-9. 2005.

Parajka, J., R. Merz, and G. Blosch, A comparison of regionalisation methods for catchment model Parameters, Hydrology and Earth System Sciences, 9, 157–171, 2005.

Rahman, J.M., S.P. Seaton, J.M. Perraud, H. Hotham, D.I. Verrelli and J. R. Coleman, It's TIME for a New Environmental Modelling Framework. Proceedings of MODSIM 2004 International Congress on Modelling and Simulation, Townsville, Australia, 14-17 July 2003. Modelling and Simulation Society of Australia and New Zealand Inc., 4, 1727-1732. 2003.

Wilkinson, S., A. Henderson, Y. Chen, SedNet User Guide, A CSIRO Land and Water client report for the Cooperative Research Centre for Catchment Hydrology, Australia, 2004.