EXPERIENCES IN DEVELOPING THE HYDROLOGY MODEL : WBNM2000.

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ABSTRACT

This paper sets out the Authors experiences in developing a sophisticated event based urban hydrology model from very simple beginnings. It highlights the capabilities of earlier models and how they have increased in complexity and functionality over the last two decades. It discusses features considered desirable in modern models and features of WBNM2000 in particular. The Authors experiences in developing WBNM2000 are discussed and advice offered to prospective model developers.

KEYWORDS

Urban; Hydrology; Model; Programming; Development; WBNM2000

INTRODUCTION

A rational approach to modelling the rainfall-runoff process can be considered to have commenced with the unit hydrograph concept of Sherman(1932) which viewed the catchment as a deterministic system transforming excess rainfall input to flood hydrograph output. Because the unit hydrograph considered input and output only, and did not specifically consider the physical properties of the catchment, it was not readily transferable to other catchments in the same region. The model of Clark(1945) attempted to address this shortcoming by utilising a time-area concentration curve for the catchment, incorporating travel times and thus indirectly catchment shape, slope and flow paths. The Clark model additionally included a single linear reservoir through which the time-area curve was routed, and so was a precursor of today's runoff routing models.

Other notable runoff routing models which followed this development included those of Nash(1960), Laurenson(1964) and Rockwood(1958). The Nash(1960) model, used a series of linear reservoirs and related the model parameters to the properties of the unit hydrograph, notably the lag time. Interestingly, both the Clark and Nash models were models of the unit hydrograph, taking as input a standard unit excess rainfall. The Laurenson model broke the connection with the unit hydrograph, producing a runoff hydrograph directly from the input rainfall hyetograph. It also relaxed the linearity assumption of the earlier models. It did however, retain a series of nonlinear reservoirs which represented the catchment time-area concentration curve.

Rockwood(1958) placed his model on a more realistic basis by dividing the catchment into sub catchments using the streams and land surface contours and representing each sub catchment by a nonlinear reservoir. This led to a plethora of models each of which aimed to represent the physically structure of the catchment. In

America notable models included SWMM (Metcalf and Eddy et al, 1971) and HEC-1, (Hydrologic Engineering Center, 1973), and in Australia, RORB (Mein et al, 1974), WBNM (Boyd, 1975), and RAFTS (Goyen and Aitken, 1976).

Key characteristics of these early runoff routing models (mid 1970s) were:

- They were developed using data from natural catchments
- Output was limited to calculating a flood hydrograph from a storm rainfall
- They were mostly applied to recorded storms rather than design storms
- Output was numerical with, at best, primitive (lineprinter) graphics

While these may be considered substantial limitations in today's world – each model was developed as a product of research with thorough calibration and validation using a considerable amount of recorded rainfall and streamflow data. The models were robust and in the hands of an experienced modeller capable of reliable simulation. Not all of today's complex multiparameter models appear to have undergone a comparable level of calibration and validation. Given the range of calibration parameters in some models, it is hard to believe this could ever be so.

In Australia , open discussion and a friendly competitive spirit between Authors of these early rival models was a distinct benefit to the evolving models.

EARLY DEVELOPMENT OF WBNM

The Watershed Bounded Network Model (WBNM) was begun as a research project in 1975 and has since that time been upgraded on several occasions to meet the needs of its users. It is a well respected Australian model with widespread usage in Australia – particularly in New South Wales.

Key aspects of development of the model are set out in summary form below;

Boyd (1975)

Fortran 66, 150 lines of model code
Developed as a research project into the hydrologic response of natural catchments.
Event model with strong physical basis including branched network structure
Model parameters related to catchment physical properties
Nonlinear routing with simple single parameter calibration
Calibrated on a good quality data set of recorded storms
Input was a hyetograph of rainfall excess, output was a calculated flood hydrograph
No ability to model changes to catchment land use, stream channels
No ability to model hydraulic structures

Boyd, Pilgrim, Cordery (1979)

FORTRAN66, 190 lines of model code
Public domain
Source code available
Features as for 1975
Numerical hard copy output

No graphics

Boyd, Bates, Pilgrim, Cordery (1987)

FORTRAN77, 2400 lines of model code (WBNMF and WBNMV)
Public domain
Source code available
Numerical hard copy output
Line printer graphics added
Flood routing in storage reservoirs added

Boyd, Rigby, VanDrie (1994)

FORTRAN77, 8100 lines of model code (plus front end, graphics and tools)
Freeware
Executable version only available (DOS)
Menu driven front end (MarxMenu) added
Graphics postprocessor (Pascal) added
Built in Australian Rainfall & Runoff design storms added
Built in Bureau of Meteorology PMP storms added
Urban catchments added
Flood routing in storage reservoirs improved
Built in culvert hydraulics added
QA - input echo & output summary produced for every run

MODELS OF THE FUTURE

As computing power and compiler sophistication increased, many new features were added to the basic hydrology models of the seventies and eighties. Today's models are no longer basic tools to calculate the hydrograph resulting from a given storm rainfall - they are now routinely used as management tools for simulation of stormwater flows within and from catchments. Over the last two decades there has been a shift away from modelling by researchers towards modeling by practicing engineers, where the models are often used in "what-if" scenarios (for example what if a flood detention basin is constructed, or what if a stream channel is cleared). This has led to changes in the features which are now considered desirable, if not essential in an event based hydrology model:

To meet these current and projected future needs, tomorrow's hydrology model will need to provide;

An attractive and easily understood graphical user interface
An ability to create design rainfall (up to PMP) for the user as model input
An ability to model both high and low flows reliably (for flooding and water quality)
An ability to model changes in land useage
An ability to model changes in the hydraulic characteristics of streams and channels
An ability to model storages introduced locally (onsite) or on the mainstream
An ability to model complex multiple destination flow diversions
An ability to graphically build the model on a catchment raster base
An ability to move easily between analysis and design of selected elements
An ability to selectively display and/or plot the resulting output

Appropriate QA documentation

Whilst water quality and continuous models may merge with event based models at some point in the future, present model differences are significant, and such broader features have therefore been omitted from this present (event based) list. It is an area however, in which change may occur in the relatively near future.

WBNM2000 - DEVELOPMENT

At the beginning of the new millennium WBNM will be twenty five years old. Over this time the model has evolved considerably, as evident in the above development chronology. Whilst ever increasing complexity has been offset by increasing functionality, it was the Authors view in early 1997 that the much added to code was in need of a major rewrite if it was to be of real use in the new millennium.

To progress this objective, a list of desirable features similar to that outlined above was assembled. One of the overriding objectives was to create, as far as possible, a simple extendable structure for the model that could serve as the base for future enhancements. To this end it was agreed that the model would be a simple 'object' based model in which the objects (subareas) receive an input of rainfall, which is transformed, based on the objects (subareas) properties, into an output hydrograph.

Subarea properties responsible for this transformation would include;

- Area and lag parameter for the subarea in a natural state
- Pervious and impervious surface proportions
- Pervious surface loss parameters
- Onsite (local) detention storage characteristics
- Mainstream (throughflow) routing characteristics
- Mainstream (local +throughflow) detention storage characteristics
- Mainstream (local + throughflow) structure hydraulics – weirs and culverts
- Topology of directly connected and diverted flows to downstream subareas

The development process might well have stalled at this point if not for the release of support libraries for Lahey Fortran 90 (LF90) that permitted windows, dialog boxes and graphics to be created and managed from LF90. Both 'Winteracter' (Interactive Software Services, 1997) and 'Realwin' (Indowsway, 1997), were trialed and found to be capable of providing the coding support needed. Realwin was ultimately selected for the task, due in the main to its lesser cost and the ease with which we were able to port and create new code for the model. The availability of this product at the time redevelopment was being planned greatly lifted the authors enthusiasm and ability to undertake the necessary coding work.

Model redevelopment and coding was split into three areas of responsibility.

- Pre-Processing - Model creation, verification, display and editing (E Rigby)
- WBNM Rewrite - Run time model check and model operation (M Boyd)
- Post-Processing - Model output display (R VanDrie)

Features to be incorporated into the initial WBNM2000 model release included;

Model Environment:

An integrated windows (95/98-NT) environment for all model components
Graphical display of model geometry and features during construction
Facility to easily move between model editing, execution and display of results
Ability to easily alter subarea properties for 'what if' scenarios
Enforced minimal input echo and output summary for QA purposes
Integrated tools to convert older model datasets and analyse rainfall
Key values retained on file for user's setup and project defaults

Model Inputs:
Design (ARR & BOM) Rainfall(s) up to PMP with option of embedment
Recorded (historic) event hyetograph(s)
Recorded hydrograph(s) or stage records for historic event(s)

Subarea Properties:
Area , Location of CG, Location of Outlet
Rainfall weighting (Automatic(Inverse square) or user input)
loss model (initial-continuing, initial and continuing proportional, Horton)
Subarea lag parameter (if not the global value)
Impervious cover (%) with separate routing of imp and perv surfaces
Mainstream/channel/minor system lag characteristics
Basin/Structure geometry & hydraulic characteristics (local (onsite) and mainstream)
Topology of flows connected directly or diverted to downstream subareas

Model Outputs:
Fully graphical user driven post processor with ability to selectively display and plot;
Rainfall inputs (At stations or as applied to subareas)
Hydrographs (At a user selected location within the model)
(Subarea inflows, local runoff and subarea outflows)
(pre and post routing including diversions)
(Also in comparison with a recorded event where appropriate)
Miscellaneous (Basin stage-time relationship - duration of overtopping)
(Inflow-Outflow volumes at a selected location)

The initial target date for release of the new model was January 1999. It is the Authors' present expectation that the initial model will now be released in July 1999. Once released, WBNM2000 will be freely available for download from the web at http://www.uow.edu.au/eng/research/water.html or from the Authors direct (email to michael_boyd@uow.edu.au). Technical and operational features of the new model are reported elsewhere by Boyd et al (1999).

A number of additional features were shortlisted for inclusion in the model but lack of resources dictated that their implementation should be deferred until after the initial model release. These deferred features include;

- The ability to underlay the model geometry during construction and in viewing output with a registered raster image (BMP) of the catchment
- The ability to create or edit a geometry graphically (by drawing or dragging with a mouse) on the registered raster.
- The ability to display and compare hydrographs for different model configurations

It is the Authors' intention to add these features progressively once the initial model is released.

In undertaking this development, the Authors have experienced some notable failures and successes - particularly in respect to expectations. Some of these experiences are set out below in the hope that someone embarking on a not dissimilar venture might benefit from our experiences.

Is your timeline realistic: Whilst the Authors are all long time users as well as developers of the 1994 Version of WBNM - the mindshift away from an orderly sequential Fortran program into 'Windows' (where multiple program segments can be running simultaneously) was relatively traumatic and a significant factor in the early work proceeding much slower than expected. Recent graduates will presumably not suffer this problem having grown up with 'Windows'. The time taken to reeducate oneself in this area should not be overlooked if you and your team are however, of the 'old school'.

Are you prepared for change: A considerable initial effort was put into the definition of the new model structure to try and minimise major structural changes during development. Change was however necessary in some areas, particularly in respect to the input datafile and output metafile. Additional and almost continual change continues to occur with the appearance of windows and dialog boxes. The rather subjective nature of window and dialog box cosmetics seems guaranteed to ensure changes will continue forever in this area. Be prepared for continuous change in the user interface.

What will the model feature: Given the wide range of features that could be included in a new model or model rewrite, it is most important to resolve at the earliest possible stage of development what the included features will be. Again, a considerable effort was put into this area in the initial stages of development of WBNM2000. Even with this effort however some features did change (as for example when we realised code for the local(onsite) basins and mainstream basins could be identical). Fortunately this oversight had minimal impact on the models structure. Aside from time and cost implications, feature changes after the model has been partly developed can lead to poor coding practices and should therefore be avoided.

Do you have the resources: All upgrades of WBNM to date have been driven by the various Authors' desire to see the model made more useful and up to date. It seems unlikely that any of the past Authors seriously contemplated the resources required to complete the task. This present rewrite has made very clear the major demand on resources associated with a rewrite of a relatively sophisticated model such as WBNM under Windows. The present rewrite has taken the three Authors some two and a half years to accomplish, and generated in excess of 20,000 lines of code. A decidedly non trivial voluntary task which the present Authors are unlikely to be able to repeat. Simpler models may well not be as demanding and perhaps with time the coding process may become more automated. In today's Window oriented computing world however, development of any useable and useful model requires major resources - be prepared!

CONCLUSIONS

Both the expectations of current computer users and complexity of the Windows interface greatly restrict the creation and development of useful technical programs by the average user. It is the Authors view, that advances in research will in the future take much longer to find their way into practice, due simply to the overhead inherent in coding these advances into useful programs. The rash of readily available technical code created during the seventies and eighties promoting new approaches to modeling in all fields, appears now to have passed. For better or worse we appear to be entering a consumer phase in modeling where technical tools are purchased 'off the shelf' by users as needed and judged more by their screen appearance than the quality of algorithms contained in their code.

Given our own experiences in developing and maintaining this model, and with the significant benefit of hindsight we offer the following advice to those interested in pursuing such development.

- Think very long and hard about the long term value of the model you are proposing
- Do not begin development of a new model unless you have the resources to complete it
- If you have improved on some aspect of a model - try first to have the improvement incorporated into a well respected existing model(with appropriate credit)
- If you feel that the improvement is fundamental and needs a new model to utilise the features - do everything in your power to develop the model. Such is the spirit of true research and development.
- If a new model is to be developed, develop a well structured task list, double all initial time estimates and make a serious effort to meet key milestones. Particularly when developing code by voluntary effort, it is very easy to defer milestones.
- Above all else never lose sight of the fact that the interesting (technical) coding is a small part of the coding package (in a typical windows package 20-30% of the total code, at most, is likely to be 'technical' - the majority of time spent coding is likely to be associated with the user interface!). Make sure you therefore understand and have a realistic grip on the time required to code the user interface.

In conclusion, model development is not for the faint hearted or resource limited. It can however be a very professionally rewarding task for those involved and ultimately is fundamental to future progress in most fields.

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