Do Gridded Hydrologic Models Have a Place in Australia?

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2-dimensional hydraulic software have undergone significant development and gained widespread acceptance within Australia over the past 10-15 years. However, 2-dimensional gridded hydrologic software have not enjoyed such a prosperous history. 2-dimensional gridded hydrologic software benefits from the relatively wide-spread availability of GIS data, which can arguably provide a more physically realistic spatial representation of hydrologic characteristics across a catchment relative to traditional “lumped” hydrologic software.

This paper discusses the potential reasons for the lack of uptake of 2-dimensional gridded hydrologic software in Australia. The paper also presents the results of investigations that have been completed to determine if 2-dimensional gridded hydrologic software can be developed using readily available information and can generate acceptable results for Australian conditions relative to other commonly used “lumped” hydrologic software.

1. INTRODUCTION

1.1. Hydrologic Software in Australia

Estimating rainfall-runoff is an important process for flood estimation, yield studies, low flow studies, reservoir operation as well as catchment and water management studies. The natural rainfall-runoff process is complex, non-linear and dynamic (Samarasinghe, 2006). Due to this complexity, the simulation of rainfall-runoff by computer software is necessarily simplified and, therefore, can only be considered an approximation of reality. There has been considerable debate regarding the best way to represent the rainfall-runoff process using a computerised approximation (Vieux, 2004).

For flood modelling purposes, hydrologic modelling in Australia over the past 30 years has typically been undertaken using “lumped” models. The term “lumped” refers to the fact that the spatial variability in hydrologic characteristics (e.g., slopes, impervious percentage, loss rates, overland flow roughness) is lumped into sub-areas assumed to be homogeneous. Therefore, the spatial variability of hydrologic parameters in such models is generally only partially represented at best. Examples of lumped models commonly used for flood routing in Australia include XP-RAFTS (Goyen & Aitken, 1976), RORB (Mein et al 1974), WBNM (Boyd et al, 1979) and URBS (Carroll, 2004).

When most of these software were developed (i.e., the 1970s), lumped representations of catchments were preferred, due to the limited computational resources available at that time. This necessitated the development of computer models with computationally simple representations of the rainfall-runoff process. The simplified representation of rainfall-runoff processes was further born out of the need to minimize the amount of data required to generate acceptable results.

1.2. The Spatial Revolution

Commercial Geographic Information System (GIS) software and associated data began to emerge in the late 1980s and has progressively gained widespread use as a means of representing spatial information. A significant amount of GIS information is now freely available from online resources, including a large amount of information that may be applied to hydrologic applications.

The public availability of GIS datasets has been led by the United States (U.S.), where it is a
requirement that most data gathered by government agencies must be available free of charge to the
general public. Hence, substantial GIS information is available in the U.S. for free from such agencies
as the United States Geological Survey (USGS).

Unfortunately, such an arrangement is not common place in most other countries. However, this is
gradually changing in Australia through agencies such as Geoscience Australia, which is building a
substantial GIS database containing a variety of different datasets extending across all states and
territories of Australia. In addition, the NASA Shuttle Radar Topography Mission (SRTM) provides a
90-metre (3 arc-second) raster digital elevation model covering all of Australia and eWater’s
Catchment Modelling Toolkit provides hydrologic soil property information on a national scale.
Therefore, there appears to be sufficient freely available GIS information to reliably represent the
spatial variability of hydrologic properties across most areas of Australia.

In recognition of the growing availability of GIS datasets worldwide, several software products have
been developed to take advantage of GIS datasets to assist with hydrologic analysis and, in particular,
to help automate the setup of hydrologic models. These include:

- ArcHydro (i.e., ArcGIS);
- CatchmentSIM; and,
- Watershed Modelling System (WMS).

As such, the advent of GIS has greatly reduced the time required to setup lumped hydrologic models.
However, despite the growing availability of GIS datasets, the lumped hydrologic models that are still
commonly utilised in Australia for flood routing do not take full advantage of these spatial datasets.
In addition, the computational limitations that inhibited the development of computationally rigorous
hydrologic algorithms in the past no longer appear to be a significant limitation.

The availability of GIS datasets and greater computational power has seen hydraulic modelling
progress from simple one-dimensional representations (e.g., HEC-2) during the late 1980s to the
present day, where very detailed and complex two-dimensional software (e.g., Tuflow, Sobek, RMA-2)
are now common place. Although there is evidence of progression in more complex and spatially
accurate hydrologic software overseas, this generally has not been reflected in Australia. This is
considered to be a result of the widespread acceptance of the aforementioned lumped models and the
lack of any alternative proven hydrologic software that can take better advantage of the spatial
information provided by GIS datasets.

### 1.3. Gridded Hydrologic Models

As discussed, lumped hydrologic software gained widespread acceptance in Australia due to their low
computational requirements and the minimal amount of information required to generate reasonable
results. However, the advent of high powered, low cost computers and the growing amount of GIS
information that is available online has somewhat negated these original advantages. This has led to
the relatively recent development of an alternate hydrologic modelling approach referred to as gridded
hydrologic models.

As the name suggests, gridded (also referred to as “distributed”) models represent a catchment using
a grid of uniformly sized cells. Each grid cell is assigned a range of hydrologic information such as
elevation, rainfall loss information, rainfall and Manning’s ‘n’ roughness values. A typical catchment
would generally comprise thousands of grid cells, each with unique hydrologic characteristics, thereby
providing a much better representation of the spatial variation in hydrologic parameter values than a
lumped hydrologic model.

A number of gridded hydrologic models are available in overseas markets (most are available in the
U.S.). These include:
- GSSHA (Gridded Surface Subsurface Hydrologic Analysis);
- Vflo™;
- MIKE-SHE;
- TOPMODEL; and,
- AFFDEF.

The purpose of this investigation was to determine if a gridded hydrologic software product could be
successfully applied to catchments in Australia using freely available GIS information.

Although it is considered that the spatial representation afforded by gridded hydrologic models better reflects the spatial variability in hydrologic parameter values, it is unlikely that gridded models will gain widespread acceptance in Australia if the additional model setup effort is not reflected by more reliable results. Therefore, the investigation also aimed to compare the relative efforts of model setup, computational time and result reliability by comparison with a hydrologic model developed using traditional lumped hydrologic software.

The GSSHA (Gridded Surface Subsurface Hydrologic Analysis) software was adopted for this investigation. GSSHA is a gridded, physics based two-dimensional hydrologic model that is developed in the U.S. by the Coastal and Hydraulics Laboratory of the US Army Corp of Engineers and can be used for event based and continuous simulations. GSSHA can be downloaded free of charge from the following website: http://www.gsshawiki.com/. Although not discussed in this paper, the GSSHA model can also be used to model other components of the hydrologic cycle, such as groundwater and surface water interaction, as well as basic sediment transport and water quality computations. The software also includes the capacity to model hydraulic structures, such as culverts, dams and weirs, as well as flow obstructions such as roadway embankments.

2. GRIDDED MODEL DEVELOPMENT

2.1. Overview

The GSSHA software was used to develop a gridded model of the Mary River catchment draining to Gympie in Queensland. This catchment was selected as it had a good distribution of active pluviographs as well as a stream gauge which could be used to assess the GSSHA model performance. In addition, calibrated WBNM models for this catchment were also available to quantify the GSSHA model performance against a traditional lumped hydrologic model. The WBNM models were developed as part of an undergraduate thesis prepared by Ryan (1999).

The Mary River at Gympie drains a 2,750 square kilometre catchment. The catchment is largely undeveloped comprising forest, crops and cleared grassland.

The GSSHA model was developed based on a grid cell size of 250 metres. For the 2,750 square kilometre Mary River catchment, this provides approximately 44,000 computational grid cells within the catchment. Each grid cell can comprise unique hydrologic parameter values, thereby, providing a detailed representation of the spatial variation in hydrologic parameter values.

In order to develop a gridded model of the Mary River catchment, the GSSHA software requires the following information for each grid cell:

- Elevation;
- Manning's 'n' roughness coefficient;
- Rainfall depths / intensities;
- Rainfall losses.

In addition, files are required defining the location and geometry of streams within the catchment.

The following sections describe how each of the input grids and stream files were generated.

2.2. Elevation Data

GSSHA uses Manning's equation to simulate overland flow in two-dimensions (refer Figure 1). As shown in Figure 1, flow between grid cells is calculated by calculating the friction slope between adjoining cells. To enable the estimation of friction slope, elevation information must be provided for each cell.
Elevations were assigned to each grid cell in the Mary River catchment model using Shuttle Radar Topography Mission (SRTM) data, which can be downloaded free of charge from the National Aeronautics and Space Administration (NASA) ftp site: ftp://e0srp01u.ecs.nasa.gov. The SRTM provides raster Digital Elevation Model (DEM) information on a near-global scale at a 90 metre grid cell size. Therefore, this dataset provides a sufficient level of detail to populate the 250 metre grid size for the Mary River model. The 90 metre SRTM was re-sampled to the 250 metre grid size using the CatchmentSIM software (Ryan, 2004).

More recently, a 30 metre global DEM was released under the ASTER GDEM moniker. This dataset is considered to provide improved coverage and vertical and horizontal accuracy relative to the SRTM data.

CatchmentSIM was also used to hydrologically condition the DEM to ensure flow could be routed throughout the entire catchment. Hydrologic conditioning refers to the process whereby the DEM is modified so that each grid cell is adjoined by a cell with a lower elevation. This ensures that flow from each grid cell can always be routed in a down-slope direction. This prevents the occurrence of “digital dams” that can detrimentally impact on the convergence of the gridded solution scheme.

The Mary River elevation grid that was developed using the SRTM data is shown in Figure 2.

2.3. Manning’s ‘n’ Roughness

As discussed, overland flow within the GSSHA model is simulated using Manning’s equation. Therefore, it is also necessary to specify a Manning’s ‘n’ roughness value for each grid cell. The Manning’s ‘n’ roughness values were assigned based on vegetation coverage GIS layers derived from 1:25,000 topographic maps. The 1:25,000 vegetation GIS layer was downloaded from the Geoscience Australia website (www.ga.gov.au). CatchmentSIM was then used to assign a Manning’s ‘n’ value to each grid cell based on the overlying vegetation type and a lookup table. The Manning’s ‘n’ lookup table is provided in Table 1 and the resulting Manning’s ‘n’ grid layer is provided in Figure 3.

<table>
<thead>
<tr>
<th>Vegetation Coverage</th>
<th>Manning’s ‘n’</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest / Shrubs</td>
<td>0.130</td>
</tr>
<tr>
<td>Rain Forest</td>
<td>0.160</td>
</tr>
<tr>
<td>Plantations</td>
<td>0.110</td>
</tr>
<tr>
<td>Orchard</td>
<td>0.100</td>
</tr>
<tr>
<td>Water Storage</td>
<td>0.400</td>
</tr>
<tr>
<td>Grass / Pasture</td>
<td>0.080</td>
</tr>
</tbody>
</table>
It should be noted that overland flow (i.e., non-channelised flow) across the majority of the gridded
surface comprises very shallow flow depths. Therefore, the effective roughness is generally substantially higher than equivalent channelised flow and therefore requires specification of Manning’s ‘n’ values significantly higher than values quoted in literature (e.g., Chow, 1959). The Manning’s ‘n’ values provided in Table 1 were initially estimated based on suggested values in the GSSHA User Manual (Downer & Ogden, 2002). They were subsequently refined as part of the GSSHA model calibration to the February 1992 flood (refer Section 3.2).

2.5. Rainfall Losses

The GSSHA model was developed in the U.S. Therefore, the software natively supports rainfall loss models that are commonly applied in the U.S. (e.g., Richard’s equation, Green-Ampt infiltration). Richards equation and Green-Ampt are considered to provide a physically realistic rainfall loss model, and the input parameters required to apply the Green-Ampt loss model could arguably be populated using the eWater CRC’s freely available ‘Hydrologic Soil Properties’ grid layer or the ‘Australia Soils Resource Information System’ (ASRIS). However, it was considered that in order to provide a reliable comparison with the WBNM software, a consistent loss model should be applied for both software products. Therefore, the initial / continuing loss model, which was adopted in the WBNM model, was also applied to the GSSHA model.

The GSSHA model does not support the initial / continuing loss model directly. The lack of an initial / continuing loss model was overcome by applying rainfall excess directly to the model. That is, global losses were subtracted from the input rainfall information before being applied to the model. The global losses for each flood simulation were adjusted so that the recorded runoff volume for each historic flood, as defined by recorded discharge hydrographs for a stream gauge located on the Mary River at Gympie, was reproduced.

2.6. Rainfall

GSSHA accepts time-varying rainfall depths or intensities at any number of gauge locations across a particular study area. The Gympie catchment has 4 pluviographs that were used to describe the spatial and temporal distribution of rainfall across the Mary River catchment. GSSHA takes the point rainfall depths/intensities and estimates the rainfall depth at each grid cell for each model time-step using one of two available interpolation algorithms (Thessien Polygons and Inverse Distance Weighted Average Interpolation). The Inverse Distance Weighted Average interpolation algorithm was applied for the Gympie GSSHA model. An extract of one of the rainfall grids generated by GSSHA for the February 1992 flood (refer Section 3.2), is shown in Figure 4. The location of the rainfall gauges (i.e., pluviographs) is also shown in Figure 4.

2.7. Streams

Although the gridded representation of topography in GSSHA provides a reasonable representation of overland flow processes, it does not provide the level of detail necessary to represent the conveyance characteristics of streams within a typical catchment. In particular, the stream cross-section is not reliably represented by the comparatively large grid cells and the overland routing applied in GSSHA requires water to move in orthogonal directions, which leads to an overestimation of stream lengths. In addition, the depths of flow within streams are typically considerably greater than overland flow depths across the majority of the catchment, which necessitates the provision of lower Manning’s ‘n’ values for streams. Therefore, streams in GSSHA are represented as separate, one-dimensional entities in the two-dimensional model domain.

Stream alignments in GSSHA were automatically delineated using CatchmentSIM. A stream was defined in CatchmentSIM using a stream area threshold (i.e., the catchment area that must be draining to a point before a stream is considered to form) of 100 km². The delineated streams are shown in Figure 5, superimposed on the elevation grid.
Figure 4: Example of Rainfall Intensity Grid Automatically Calculated by GSSHA for each Timestep

Figure 5: Delineated Streams Based on a Stream Area Threshold of 100 km²
In addition to the geometric alignment of all streams in the catchment, information on the flow carrying capacity of each stream channel segment must be provided. GSSHA provides the option of incorporating surveyed or trapezoidal cross-section information. Although it would be desirable to incorporate actual surveyed cross-sections for each channel segment, this type of information would typically only be available for relatively small portions of an overall catchment, if at all. Therefore, methods were investigated to determine if a suitable trapezoidal channel size could be derived for each channel segment based on more readily available information.

Channel widths and depths were subsequently estimated for each channel segment using empirical relationships that were developed for Queensland catchments by Tennakoon & Marsh (2007). These relationships used catchment area as the only input parameter. Although the research presented by Tennakoon & Marsh, suggested that other variables such as mean annual discharge or 2-year ARI discharge generally provide a more reliable method of estimating stream depth and width, this type of information is not as readily available for all stream segments. The equations adopted to estimate stream length and stream width are included as Eq. (1) and (2).

\[ W = 12.4 \times A^{0.17} \]  
\[ D = 1.31 \times A^{0.10} \]

Where: \( W \) is the top channel width in metres, \( D \) is the mean channel depth in metres, and \( A \) is the total catchment area draining to the stream segment in square kilometres.

The catchment area draining to each channel segment was automatically calculated using CatchmentSIM, which then allowed the stream width and length to also be calculated automatically using the above equations. This was used in conjunction with a constant channel side slope of 1 vertical : 2 horizontal to provide all of the required input information for the trapezoidal channels within GSSHA.

### 3. RESULTS

#### 3.1. Overview

Following population of the GSSHA model grid layers, stream channel files and associated model control files, the model was calibrated using available pluviograph and stream gauging data for a flood that occurred in February 1992. Following calibration to the February 1992 flood, the model was verified using available rainfall and stream flow data for a smaller flood that occurred in February 1995.

Hydrologic model calibration refers to the process whereby model parameters that are not known with a high degree of certainty or that may vary between locations or floods are adjusted within reasonable limits until the model reproduces observed/recorded discharge hydrographs. For traditional lumped hydrologic software, parameters that are typically adjusted as part of the calibration process include loss rates (which are used to reproduce the observed volume of runoff) and storage/lag parameters (which are used to reproduce the shape and timing of the observed hydrograph). Some lumped models also incorporate a non-linearity coefficient, however, this is generally kept constant. Ideally, the same set of calibrated model parameters can be used for subsequent simulations with little or no further adjustment. However, it is quite common to modify loss rates for additional lumped model simulations as they can vary due to differences in factors such as antecedent wetness conditions, vegetation interception, minor depression storage as well as seasonal variations (e.g., evapotranspiration). There is also evidence to suggest that loss rates vary based on the severity of the of the flood event. For example, for the ACT, Australian Rainfall and Runoff suggests adopting a continuing loss rates varying between 3.6 mm/hr for the 2 year ARI down to 1.0 mm/hr for events greater than the 50 year ARI (Institution of Engineers, Australia, 1987).

For a gridded model, such as GSSHA, loss rates are also typically adjusted in order to reproduce the observed volume of runoff. The only other key gridded model input parameter that is not known with a high degree of certainty are the Manning's 'n' roughness values for the two-dimensional grid cells as
well as the one-dimensional channel segments. The Manning's 'n' coefficients control the speed at which runoff travels across the catchment. Therefore, it can be considered analogous to the lag/storage parameters that are typically adjusted as part of the lumped model calibration process. Similar to the lumped model calibration, loss rates may be adjusted as part of subsequent simulations.

The results of the calibration and verification simulations are presented in the following sections.

### 3.2. February 1992 Flood Simulation

The February 1992 flood generated a peak discharge of approximately 8,500 m$^3$/s at the Gympie stream gauge. The February 1992 flood was a significant event, generating a peak stage of 21.95 metres, slightly less than the predicted 50-year ARI flood stage at Gympie of 22.90 metres (Aon Australia, 1999)

Several iterative simulations were completed using the GSSHA model for the 1992 flood. Manning's ‘n’ roughness values for the stream channel segments and grid cells were adjusted to best replicate the peak discharge and timing of the recorded discharge hydrograph at Gympie for the 1992 flood. The global model loss rates were also adjusted to best replicate the recorded volume of runoff during the 1992 flood. The recorded discharge hydrograph at the Gympie gauge is provided in Figure 6. The discharge hydrograph generated by the GSSHA and WBNM models is also superimposed on Figure 6 for comparison. The rainfall hyetographs for the Maleny and Imbil gauges, which are located within the upper and central sections of the catchment respectively, are also provided on Figure 6.

![Comparison of recorded, WBNM and GSSHA hydrographs for the February 1992 flood](image)

3.3. February 1995 Flood Simulation

The February 1995 flood was used to determine if the model parameters that were adopted as part of the GSSHA model calibration could generate acceptable results for other floods of differing severity. That is, the Manning’s ‘n’ parameters that were adopted in the final February 1992 flood simulation were also retained for the February 1995 simulations. Only the global loss rates were modified to reproduce the recorded runoff volume. As discussed, it was considered reasonable to modify the adopted loss rates between subsequent simulations due to potential differences in antecedent moisture conditions, vegetation interception and minor depression storage.
The recorded discharge hydrograph for the February 1995 event at Gympie is provided in Figure 7. The flood hydrographs generated by the GSSHA model and the WBNM models are also provided in Figure 7.

Figure 7 Comparison of recorded, WBNM and GSSHA hydrographs for the February 1995 flood

It should be noted when reviewing these results that in order for the WBNM model to provide a reasonable reproduction of the recorded hydrograph it was necessary to adjust both loss rates and lag parameters relative to the 1992 simulation. However, the GSSHA model provided a reasonable reproduction of the recorded hydrograph by only adjusting loss rates.

4. DISCUSSION

4.1. Model Results

As shown in Figure 6, the GSSHA model provides a similar reproduction of the February 1992 flood hydrograph when compared to the WBNM model. In particular, the rising limb of the hydrograph comprises a similar shape and rate of rise, although the GSSHA hydrograph peaks slightly before the WBNM hydrograph. The runoff volume predicted by the GSSHA model also shows a good agreement with the recorded hydrograph and the WBNM model. As shown in Figure 6, both the WBNM and GSSHA hydrographs peak before the recorded hydrograph. A definitive reason for this could not be established, however, the significant difference in timing between the peak of the rainfall hyetograph and peak of the discharge hydrograph may indicate non-representative rainfall data or a bias in the recorded rainfall or discharge hydrograph information.

Figure 7 shows that the GSSHA hydrograph for the February 1995 flood provides a reasonable reproduction of the recorded flood hydrograph at the Gympie gauge, although both the GSSHA and WBNM hydrographs again peak prior to the recorded hydrograph at Gympie. Figure 7 shows that the GSSHA model arguably provides an improved estimate of the 1995 hydrograph relative to the WBNM model, despite alternative loss rates and lag parameters being adopted in the WBNM model to try and improve the hydrograph reproduction. However, both the WBNM and the GSSHA models show a second peak on the discharge hydrograph, which is not evident in the recorded hydrograph.
The results of the calibration and verification simulations show that the GSSHA model was able to provide an improved reproduction of the February 1995 flood hydrograph. In addition, it is evident that a single set of GSSHA input parameters are capable of generating reasonable results for a number of different floods (although loss rates needed to be modified between both simulations). This does appear to offer an improvement on lumped models, where it may be common to adopt different input parameters in order to reproduce historic floods. In addition, as the GSSHA software is more physically based, it is not dependent on regional parameters like some lumped software.

4.2. Model Setup Time

Gridded hydrologic models require a significant amount of additional information relative to traditional lumped hydrologic models. As a result, the comparative model setup time for a gridded hydrologic model is considered to be larger. In addition, the preparation of all required grid and stream layers requires specialized software to help automate the population of the required input information. That is, a gridded hydrologic model cannot be developed “by hand” like a lumped hydrologic model.

A common criticism of gridded hydrologic models is that the setup time is considerably longer than lumped hydrologic models. However, by using a suitable GIS interface, models such as GSSHA can be setup in a highly automated and relatively quick fashion. CatchmentSIM and WMS are the two GIS interfaces that can directly create GSSHA input files.

The greater number of input parameters required for a gridded model does also arguably increase the difficulty and time required to suitably calibrate the model. Calibration of lumped models typically involves modification of loss rates to reproduce recorded runoff volumes and a “lag” or storage coefficient to reproduce the shape and timing of the recorded hydrograph.

As discussed, calibration of the GSSHA model was also completed by adjusting the global loss rate to reproduce the recorded volume of runoff for each flood. As a global loss rate was applied to the GSSHA model, this component of the gridded model calibration did not increase the calibration time relative to a lumped model.

The only other gridded parameter that was adjusted as part of the calibration was the Manning’s ‘n’ roughness values, which impacts on the speed of overland runoff and, therefore, can be considered equivalent to a “lag” parameter. Although it is possible to adjust Manning’s ‘n’ values for individual grid cells, as discussed in Section 2.3, Manning’s ‘n’ values were assigned based on vegetation coverage and associated global Manning’s ‘n’ values for each vegetation coverage. For this particular catchment, six different vegetation coverages extended across the catchment, necessitating the adjustment of six different Manning’s ‘n’ values as part of the calibration. Therefore, calibration by modifying Manning’s ‘n’ parameters in gridded models would generally be more time consuming than adjustment of global lag parameters in lumped models. However, this could be overcome somewhat by adopting default Manning’s ‘n’ values for different land use / vegetation coverages and then applying a global adjustment factor to modify all roughness values up or down simultaneously.

4.3. Simulation Time

As discussed, most traditional hydrologic models applied simplified hydrologic calculations in order to minimize computational requirements. As a result, on modern day dual core Pentium P.C.’s, most event based lumped hydrologic models will complete all required hydrologic calculations in just a few seconds.

The hydrologic calculations employed in gridded models are more complex, and need to be performed on a far greater number of computational units (i.e., grid cells). This results in significantly longer simulation times relative to lumped hydrologic models. The February 1992 simulation, which was a 5 day simulation, took approximately 31 minutes to complete on a dual core Pentium 2.4 GHz PC using a 10 second time step. The February 1995 simulation, which was a 4 day simulation, took approximately 22 minutes to run to completion using a 10 second time step on the same PC.

Although this is clearly a big increase in computational time it should also be recognized that the simulation times are not unreasonable relative to simulation times for modern two-dimensional hydraulic software.
4.4. Other Considerations

There are a number of other potential advantages to gridded hydrologic models that should be considered, including:

- Gridded hydrologic models typically provide a significant amount of additional output information as compared to lumped models. GSSHA will create grid layers showing the spatial and temporal variation in rainfall intensity/depths across the catchment. It will also create grid layers showing the predicted depth of inundation across the catchment, providing a rough indication of potential flood extents. In addition, discharge hydrographs can be extracted at any grid cell across the catchment. This provides a significant advantage relative to lumped hydrologic models, where discharges can only be extracted at the outlet of each subcatchment. These additional outputs can also be beneficial in communication of flood modelling results to the general public and key stakeholders.

- Although there are far more parameters involved in using GSSHA, they are almost entirely physically based as opposed to general calibration parameters such as WBNM’s ‘C’ factor. That is, they can usually be measured or approximated based on available GIS data. This means that models such as GSSHA may be more reliable in areas where no calibration data is available or land-use changes have precluded its use.

- Gridded models do not require a subcatchment break-up and hence the inherent subjectivity involved with picking subcatchment outlets and assuming homogeneous subcatchments is removed.

- Most gridded models also contain hydraulic algorithms (e.g., to represent pipes and water storages) that can be ‘switched on’ with minimal additional data requirements. Thus the model can be expanded to one that includes stage calculation and inundation mapping far easier than typical lumped hydrologic models.

- Future trends in data collection will likely see greater amounts of hydrologic data available at finer spatial resolutions than currently available. Thus, it could be argued that gridded hydrologic models have more potential for improvement into the future as opposed to lumped hydrologic models.

Nevertheless, there are some disadvantages associated with using a gridded hydrologic model in Australia. This includes:

- The GSSHA software does not natively support the initial / continuing loss model. Therefore, it is not currently possible to incorporate spatially varying initial / continuing losses within GSSHA, which negates some of the benefits of using a gridded model. Additional effort is also required to manually subtract the appropriate losses from the raw rainfall data prior to input to the model.

- The 2-dimensional overland flow Manning’s ‘n’ values employed in GSSHA are generally significantly higher than Manning’s ‘n’ values published in literature. This may lead to confusion, inappropriate specification of roughness values and unreliable results if traditional Manning’s ‘n’ values are simply extracted from textbooks by inexperienced users.

- The large data requirements for gridded models require specialised GIS software to prepare the required input datasets.

- In order to produce acceptable results for this investigation it was necessary to incorporate 1-dimensional channel elements. This requires channel depths and top widths to be defined as a minimum for each watercourse reach. This investigation utilised a relationship between channel depth / top width and contributing catchment area, which was previously developed for Queensland catchments. However, such relationships or channel depth/width information may not be available for all areas of Australia.

- The freely available GIS and elevation information used for this study generally only provides a “broad-scale” appreciation of the variability in hydrologic parameter values. Therefore, this freely available input data is only considered to be appropriate for larger catchment areas. Nevertheless, as GIS datasets become more detailed and more readily available, this is likely to become less of a restriction.

- The initial time required to calibrate a gridded hydrologic model will generally always be larger than an equivalent lumped hydrologic model. In addition, the simulation time for a gridded hydrologic model is considerably higher than a lumped model. However, the GSSHA software does include a facility to incorporate optimisation algorithms which have the potential to help automate the calibration process.
5. CONCLUSION

This paper has demonstrated that gridded hydrologic models can be developed for Australian catchments using free, readily available, online data. Although specialized software is required to develop the required input data, gridded hydrologic models provide better spatial representation of hydrologic input parameters and useful insight into the rainfall-runoff process.

The GSSHA model developed for this paper was able to provide a good reproduction of recorded hydrographs for two floods in the Mary River catchment draining to Gympie relative to a lumped WBNM model. And unlike the WBNM model, the GSSHA model was able to produce acceptable results for both floods with the same lag (i.e., roughness) parameters. It is considered that this may be a result of the physically based representation of the catchment within the gridded model and the non reliance of GSSHA on any general lag parameters.

The gridded model does show some improvements relative to the lumped WBNM model, however they are relatively minor in nature. However, when the other advantages of gridded hydrologic models are considered, a good case may be made for the further evaluation of these models on Australian catchments.

6. FUTURE WORK

Further research is planned to test GSSHA in other parts of Australia. We also plan to investigate:

- The impact that the adopted grid size has on results;
- The impact that the characteristics of the 1-dimensional stream network (e.g., stream area threshold value) has on results;
- 2-dimensional overland and 1-dimensional channel travel times and whether more than one combination of overland and channel roughness values can produce similar results;
- Whether the physically based loss models within GSSHA can provide more reliable loss estimates than the initial/continuing loss models typically applied in Australia.

It is also planned to further develop CatchmentSIM to ensure tight integration with GSSHA for both inputs and outputs.

7. ACKNOWLEDGMENTS

The authors would like to acknowledge the input of Dr Charles Downer from the Coastal Hydraulics Laboratory of the United States Army Corp of Engineers. Dr Downer responded to many queries regarding the practical application of the GSSHA software.

8. REFERENCES


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