Stormwater Runoff Modelling in an Urban Catchment to Plan Risk Management for Contaminant Spills for Stormwater Harvesting

Baden Myers [1], John Awad [1,3,*], David Pezzaniti [2], Dennis Gonzalez [3], Declan Page [3] and Peter Dillon [3]

[1] Science Technology, Engineering and Maths (STEM), Scarce Resources and Circular Economy (ScaRCE), Mawson Lakes Campus, University of South Australia, Mawson Lakes, SA, 5095, Australia; baden.myers@unisa.edu.au
[2] Science Technology, Engineering and Maths (STEM), Mawson Lakes Campus, University of South Australia, Mawson Lakes, SA, 5095, Australia; City of Salisbury, 34 Church St, Salisbury SA 5108, Australia; DPezzaniti@salisbury.sa.gov.au
[3] CSIRO Land and Water, Waite Laboratories, Waite Rd., Urrbrae, SA 5064, Australia; Dennis.Gonzalez@csiro.au (D.G.); Declan.Page@csiro.au (D.P.); pdillon500@gmail.com (P.D.)
* Correspondence: John.awad@mymail.unisa.edu.au; Tel.: +61-470-330-821

Table S1. Pollutant characteristics of MASS and CONCENTRATION based pollutant loads at downstream of the Cobbler Creek pump station with continuous baseflow

	CONCENTRATION [a]			**MASS**		
Baseflow (L/s)	**Travel time (mins)**	**Time to peak concentration (mins)**	**Duration (hrs)**	**Travel time (mins)**	**Time to peak concentration (mins)**	**Duration (hrs)**
5	78	204	8.89	97	228	9.05
50	44	102	3.53	48	108	3.52
100	36	84	2.68	36	84	2.7

[a] The analysis involved the simulation of a four day period with no rainfall. A 20 Ton pollutant (MASS) or 20 kL fluid pollutant (CONCENTRATION) was added.

Table S2: Dry weather travel time statistics for a 20 kL and 40 kL spills without baseflow and with 5 L/s baseflow.

Spill volume		**20 kL**				**40 kL**			
Baseflow		**0.0 L/s**		**5.0 L/s**		**0.0 L/s**		**5.0 L/s**	
Site #	**Distance (m)**	**Quality routing error (%)**	**Volume routing error (%)**	**Quality routing error (%)**	**Volume routing error (%)**	**Quality routing error (%)**	**Volume routing error (%)**	**Quality routing error (%)**	**Volume routing error (%)**
Site 1	5100	-36.5	-118.8	10.7	-0.6	-98.5	-63.4	13.9	-0.7
Site 2	5180	-43.9	-119.2	10.4	-0.6	-100.2	-37.5	14.3	-0.7
Site 3	4090	-29.2	-106.6	9.9	-0.5	-87.9	-87.9	12.4	-0.6
Site 4	3390	-56.0	-100.8	10.4	-0.5	-86.1	-67.6	12.1	-0.6
Site 5	3380	-93.0	-118.2	9.8	-0.6	-83.4	-103.5	10.9	-0.9
Site 6	1630	-81.0	-81.0	9.6	-0.4	-67.7	-67.7	10.3	-0.5
Site 7	2508	-109.6	-109.6	11.1	-0.6	-92.1	-92.1	11.6	-0.7
Site 8	2100	-74.6	-83.2	9.3	-0.3	-74.6	-83.2	9.3	-0.3
Site 9	6660	-264.2	-264.2	15.1	-1.5	-229.2	-229.3	12.3	-0.3
Site 10	2060	-75.0	-87.6	10.1	-0.5	-56.4	-75.4	10.1	-0.5
Site 11	4280	-37.8	-92.6	10.1	-0.5	-47.2	-64.8	18.0	-0.3
Site 12	3795	-59.0	-95.1	8.9	-0.4	-50.7	-76.1	12.4	-0.5
Site 13	2480	-105.4	-105.4	11.0	-0.5	-71.1	-85.8	11.3	-0.7
Site 14	2160	-32.7	-104.3	11.1	-0.5	-84.7	-84.7	10.9	-0.7
Site 15	5865	-49.8	-120.7	10.5	-0.6	-15.9	-96.2	13.3	-0.8
Site 16	4360	-124.0	-124.0	9.8	-0.8	-113.6	-113.6	11.4	-0.9
Site 17	4395	-34.0	-98.8	9.3	-0.5	-85.4	-85.4	11.6	-0.5
Site 18	6800	-20.9	-87.5	16.6	-0.4	-21.5	-80.0	19.4	-0.4

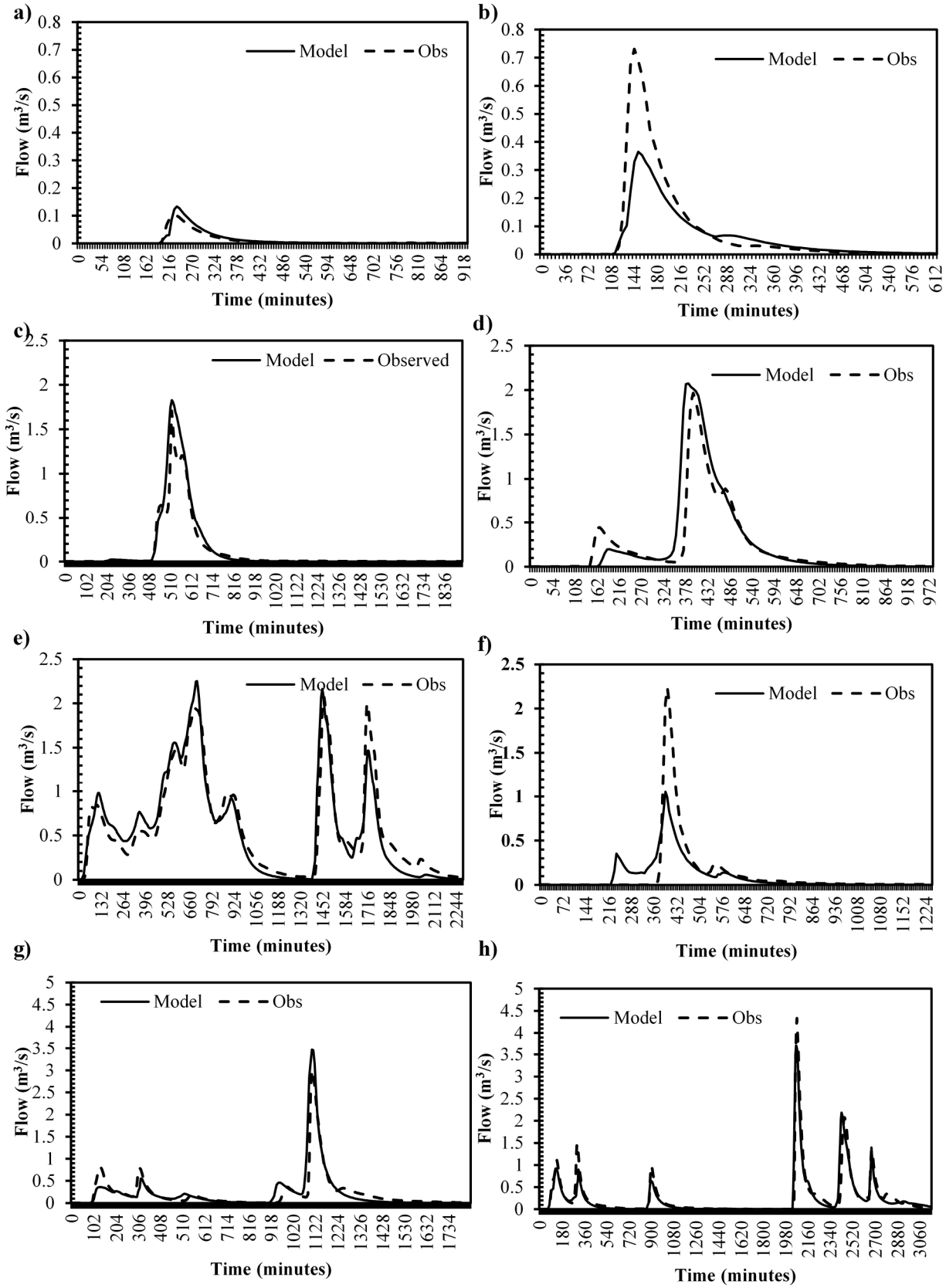

Figure S1. Observed and model simulated data for a) Event #1, b) Event #2, c) Event #3, d) Event #4, e) Event #5, f) Event #6, g) Event #7 and h) Event #8

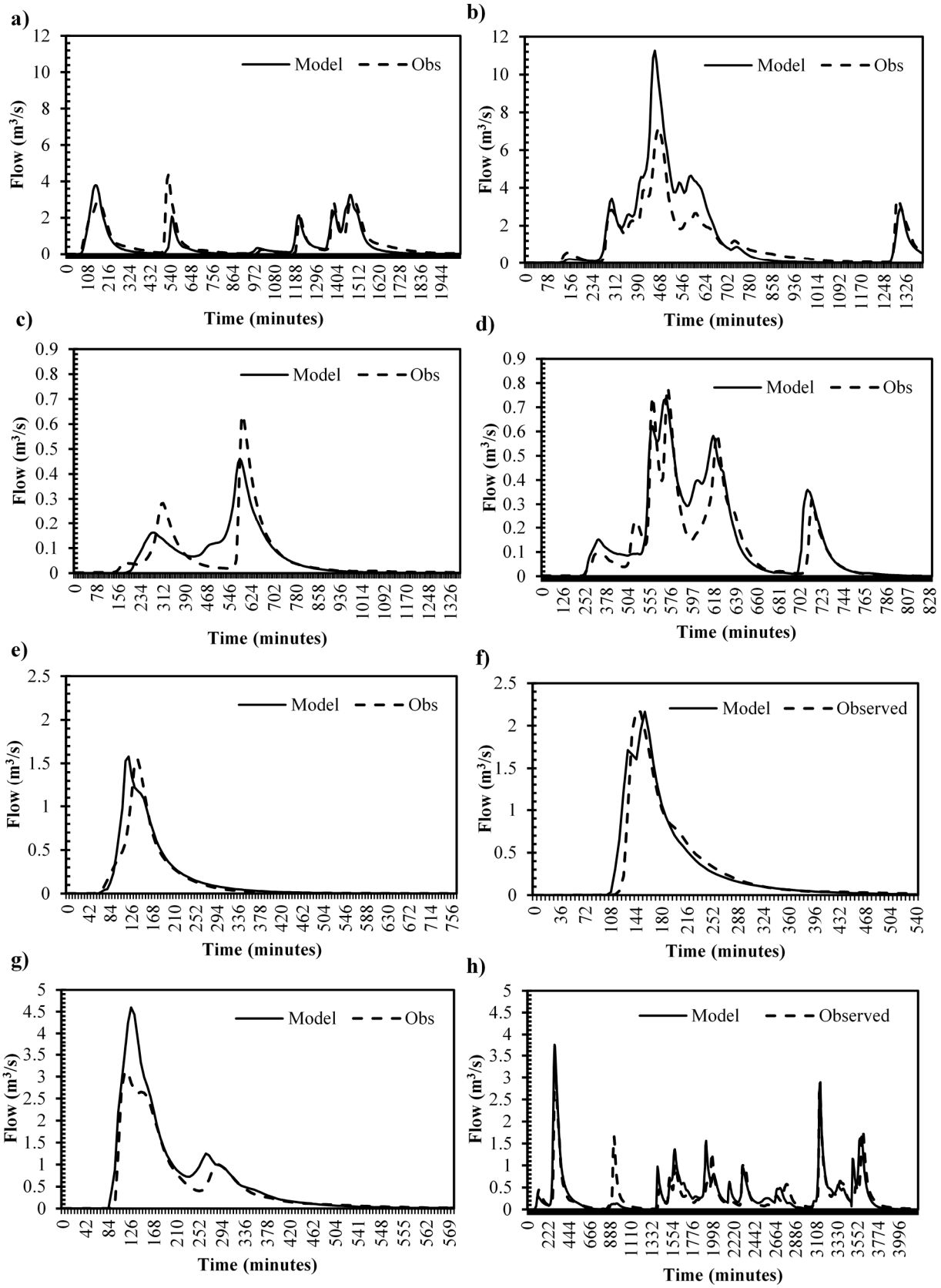

Figure S2. Observed and model simulated data for a) Event #9, b) Event #10, c) Event #11, d) Event #13, e) Event #14, f) Event #16, g) Event #17 and h) Event #18

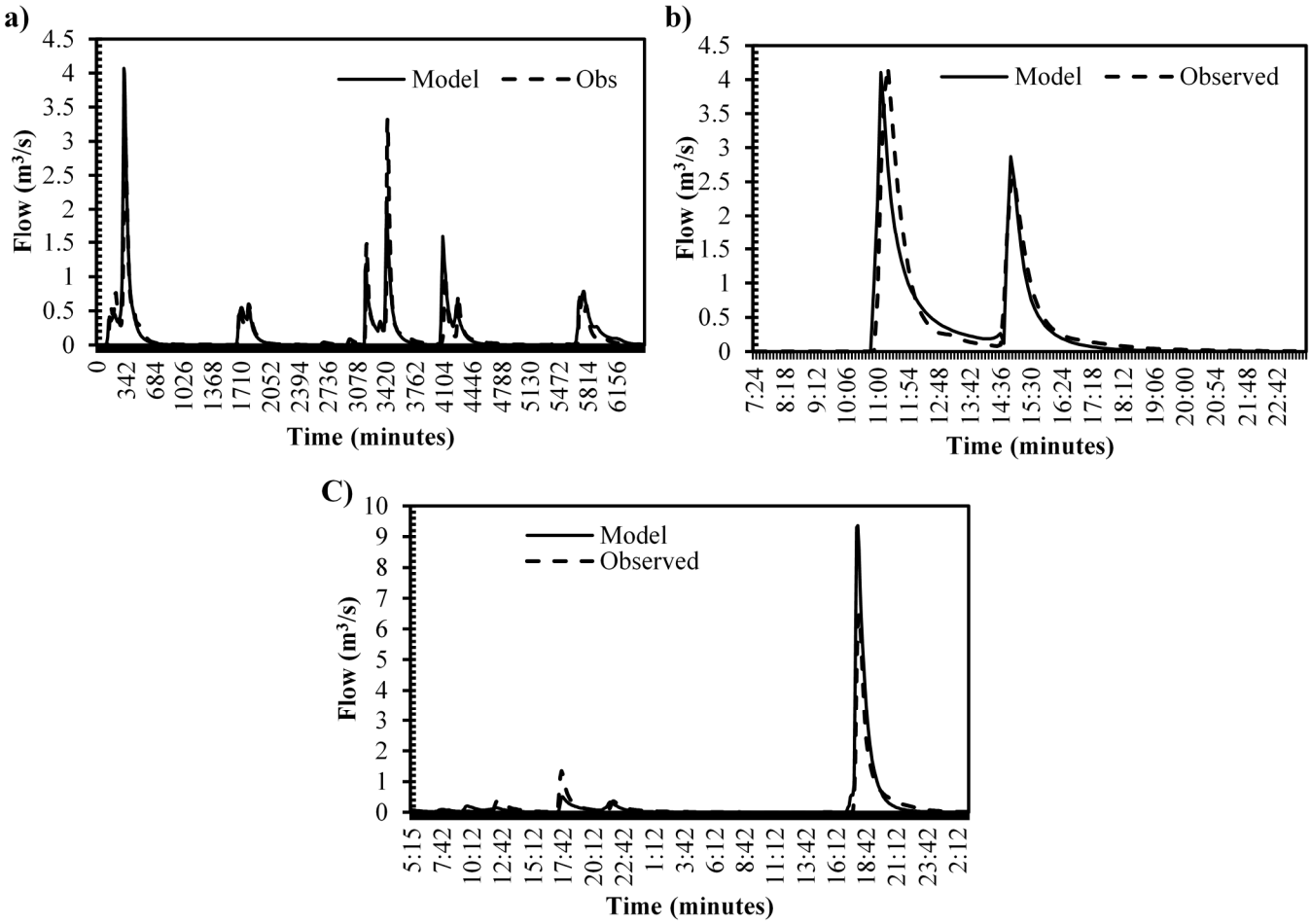

Figure S3. Observed and model simulated data for a) Event #19, b) Event #20 and c) Event #21

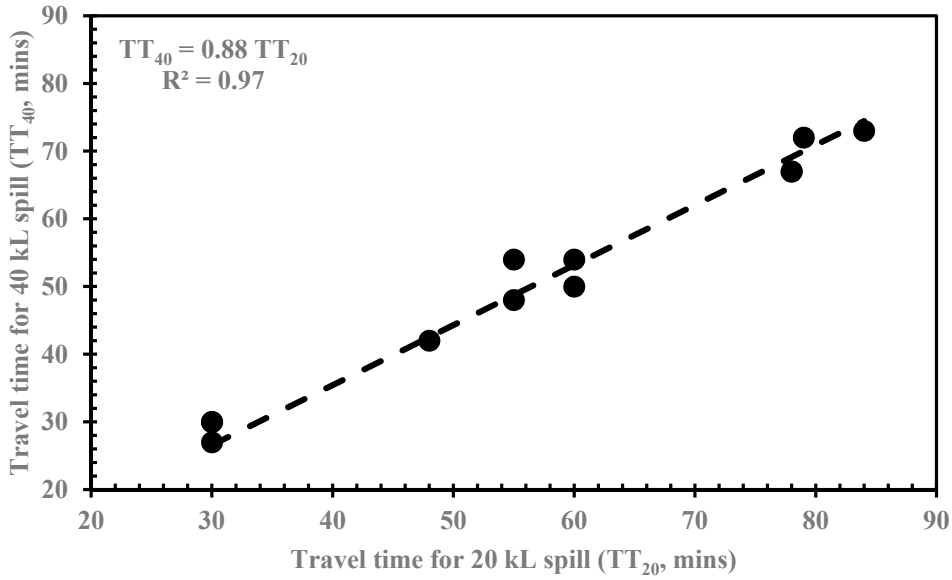

Figure S4: Travel time for 20 kL spill vs 40 kL spill event

S1. Commentary on Sources of Error

There are several sources of error that may have influenced the quality of the model calibration. These include the nature of rainfall data, parameter variation and gauge error. These are discussed further in the following sections.

S1.1. Rainfall data

The quality of gauge rainfall data is a possible source of error in this study. Other authors acknowledge that it is 'virtually impossible to obtain a precise and accurate measure of rainfall' [1] and that rainfall has a significant impact on runoff estimation.

Errors in rainfall can occur in rainfall data collection by a gauge. Sources of error in rainfall measurement in the field include losses due to wind deformation above the gauge collection orifice, as well as gauge wetting and splashing. In particular, pluviograph rainfall is known to under-record low rainfall intensities (< 0.25 mm/h) [1].

Other sources of error in the rainfall data may be in the attribution of rainfall data in this study to the subcatchments of the PCSWMM model on the basis of elevation using data from Parafield gauge (023013) and Little Para gauge (A5040528). This method was adopted to capture the spatial variation of rainfall which may occur across the catchment due to elevation. This was considered to be the best solution given the availability of short timestep rain gauge data.

For example, when only the data for Parafield Airport (023013) are used uniformly across the catchment, there is a reduced quantity of runoff produced by the model. To illustrate, using Event 18 as a case study, the predicted flow is reduced from 143800 m^3 to 136500 m^3 when the Little Para gauge (A5040528) is excluded. This is because the gauge at Little Para typically records higher rainfall than the gauge at Parafield for most events and shows the importance of attributing rainfall data correctly across the catchment when using multiple gauges. In this study, rainfall data was attributed based on elevation of the sub-catchment, and there were only two gauges with appropriate quality data to select from. The availability of additional rainfall data that would capture variation in rainfall patterns, particularly from more localised storms. A further degree of accuracy may be possible through the adoption of radar rainfall data which was not available from the Australian Bureau of Meteorology in the period of this study.

S1.2. Model Parameter Variation

There may be some variation in the model parameters throughout the catchment that were not captured in this study. For example, there may be variations in the

- Percentage of connected impervious area (due to ongoing greenfield and infill development)
- Manning's 'n' value of the catchment pervious and impervious surfaces
- Manning's 'n' value of the conduits in the stormwater network
- Soil properties (infiltration, available storage depth)

These variations were not explored because with only a single flow gauge at the catchment outlet (point of harvest) there was little basis on which to examine the effect of parameter variation catchment wide. Additional flow gauges throughout the catchment would allow for different portions of the catchment to be independently calibrated based on observed flows, however with a single gauge it was considered more appropriate to uniformly adopt calibrated data within the ranges recommended for SWMM modelling from reference material (such as Rossman [2]).

Wagener, *et al.* [3] also indicate that 'hydrological models are not typically capable of fitting all system response modes with a single parameter set due to the presence of structural errors', which may explain why some events have a very good fit (Event 18, Figure S3h) and others less so (Event 1, Figure S1a). Examples of such structural errors include parameters or variation in parameters that are not captured by a model. Variation of soil parameters over seasons, for example, are one such parameter not accounted for. The occurrence of pipe maintenance works, such as removing litter or pipe replacement, would also change the Manning's 'n' value of the hydraulic conveyance network, an aspect which has not been recorded.

S1.3. Errors in Observed Flow Data

It is possible that successful calibration of some events was affected by errors in observed flow data. The source of this error is unknown, but it would appear that there is a significant discrepancy between the simulated and observed data for Event 16 (Figure S2f) which was not found to occur to such an extent for the other storm events. The peak flow in was over-predicted and time-shifted from the observed flow.

The reason for the apparent time shift is unknown, but may be due to discrepancies between gauged rainfall and the actual occurrence of rainfall over the catchment – for example, a localised storm over the gauged area of the catchment that in the model was uniformly applied across a broader area (increasing flow prediction and reducing time of travel). The model did often over-predict the peak flow of higher flow events (such as Event 18). This may be due to an inappropriate relationship between flow depth and flow rate for the flow gauge rating table used to determine flow rate at the Parafield drain gauge during high flow events. Gauge ratings for high flow events are always harder to conduct as they are less frequent, and may be exacerbated by the potential for overflow to occur in the stormwater network during intense storms, and as such the depth of flow is not adequately representing the volume of flow. It has been suggested that the depth/flow rate relationship of the Parafield drain gauge be further investigated to confirm the validity of this relationship for high flows (those in excess of approximately 6 m^3/s).

References:

1. Ladson, A.R. Hydrology : An Australian Introduction. Oxford University Press, South Melbourne, Victoria, Australia, 2008.
2. Rossman, L.A. *Storm Water Management Model User's Manual Version 5.0*; Environmental Protection Agency, Washington, DC: 2010.
3. Wagener, T.; Gupta, H.V.; Wheater, H.; Wheater, H.S.; Gupta, H.V. *Rainfall-runoff modelling in gauged and ungauged catchments*; Imperial College Press, Distributed by World Scientific: London, 2004.