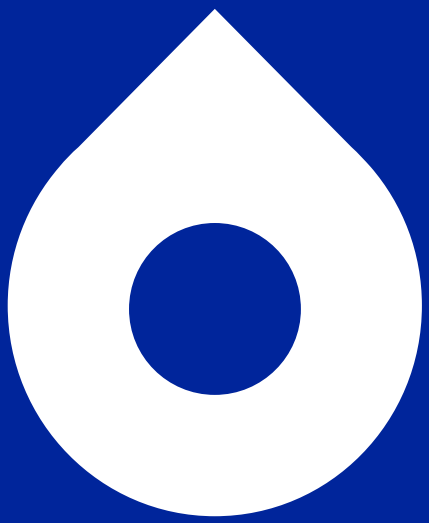
Millstream Overflow Performance Reporting

Jan **2025 to Dec 2025**



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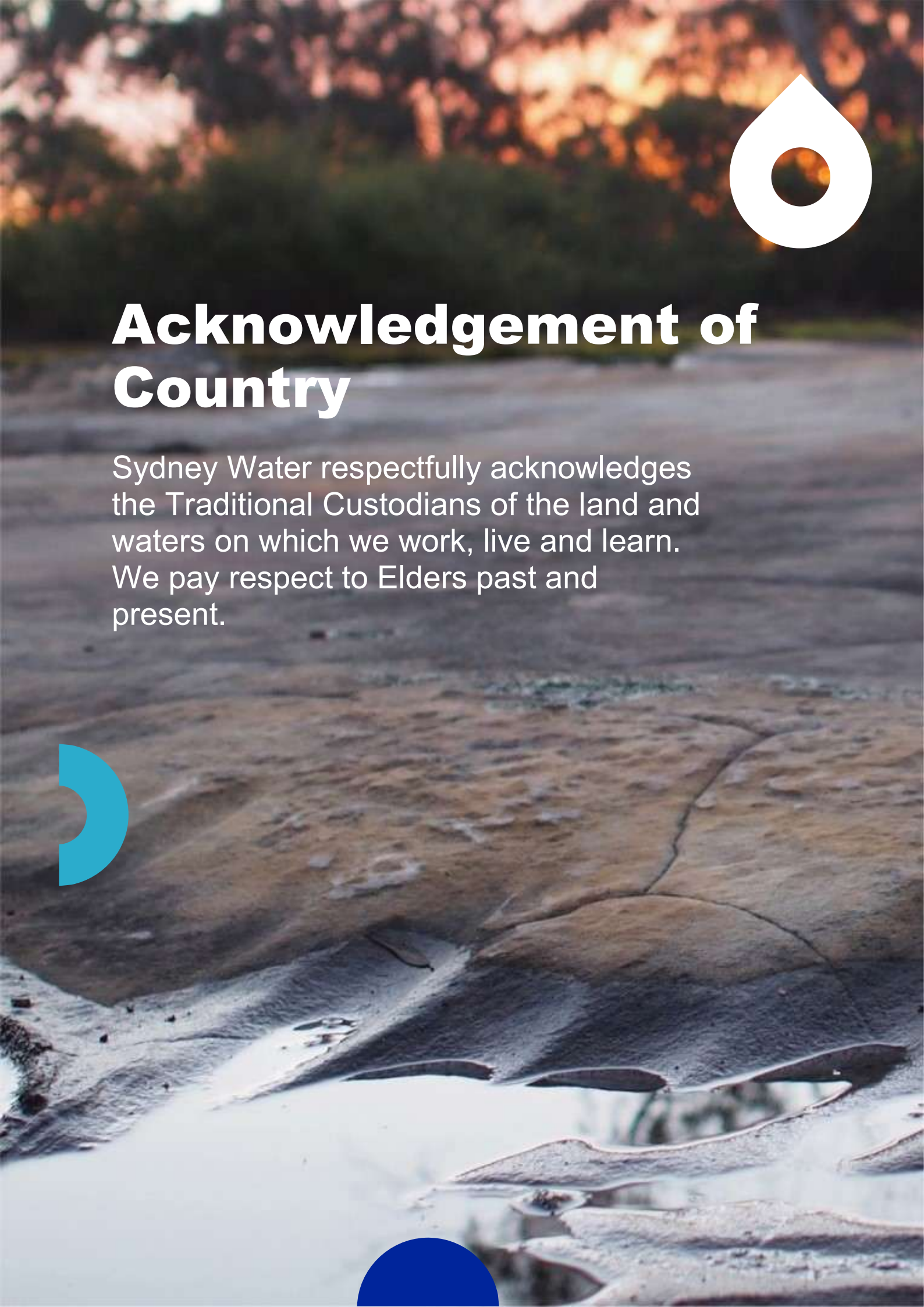

Acknowledgement of Country

Sydney Water respectfully acknowledges the Traditional Custodians of the land and waters on which we work, live and learn. We pay respect to Elders past and present.

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1. Introduction

1.1 Background

The Mill Stream ERS discharge is located on and potentially impacts air, land and waters of the Kingsford Smith Airport Site. Given this, it requires authorisation (Licencing) under Federal Legislation (Airport Act) and Airport Environment Protection Regulations. The Licence has a period of 3 years. At the end of 3 years a further Licence must be requested.

There are currently eight sewer overflows from SWSOOS1, SWSOOS2N, SWSOOS2S and SP0038 that discharge wet weather overflow into Mill Stream via stormwater channels. These overflow discharge frequency and volumes are causing issues where the Environment Protection Authority (EPA) and the Airport Authority are expressing great concerns.

The ERSs are located on federally owned land at Sydney Airport and has potential air and water impacts. This requires Sydney Water to gain an authorisation under the Airports (Environment Protection) Regulation (AEPR) 1997, issued by the Department of Infrastructure, Transport, Regional Development and Communications (DITRC) to operate this ERS.

The locations of the eight overflows designed to discharge to Mill Stream are shown in **Figure 1** Millstream overflow location map

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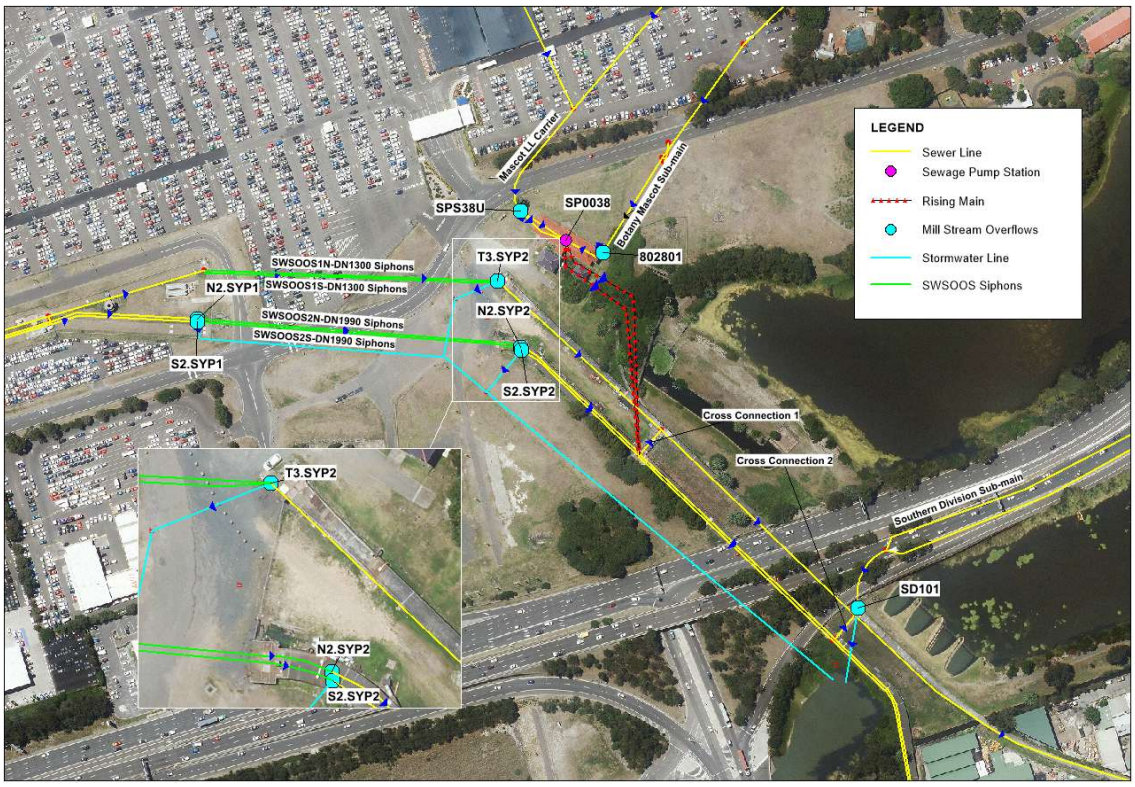
Figure 1 Millstream overflow location map



1.1 Millstream Overflow performance

The modelled overflow performance is an average, calculated against an existing time series of rainfall that represents a range of weather conditions (10 years, 1985 – 1994). This time series is used by Sydney Water to provide a consistent and comparable assessment of the wastewater system performance as the system is changed through maintenance activities, upgrades, and ongoing development/population growth. The model is also calibrated with data sourced from flow gauges, level and pressure sensors, that continually monitor the network. This method is consistent with the process Sydney Water uses for reporting compliance with our Environment Protection Licences regulated and assessed by the NSW EPA. However, it is an averaged metric and cannot be used to compare to overflow activity observed during smaller weather periods, particularly more extreme periods such as flooding or drought. To address that **Figure 3**, represents how that average performance sits within the seasonal variability accounted for in the modelled time series, and as could be directly observed year to year at Mill Stream.

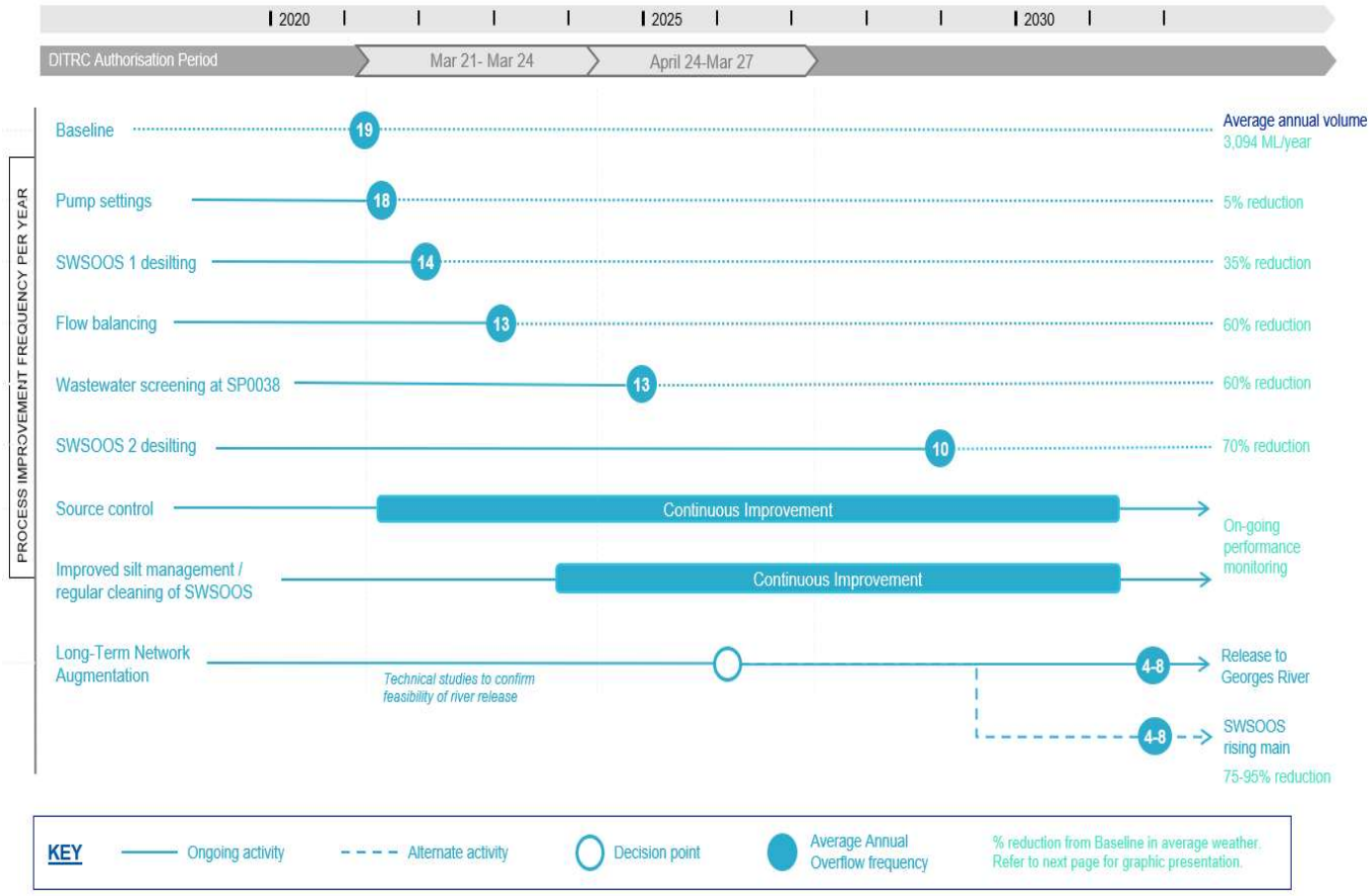


Figure 2 Millstream plan on a page (1), indicating overflow performance from asset works

Please note: performance beyond 2023 is an estimate based on assumed benefit from future works

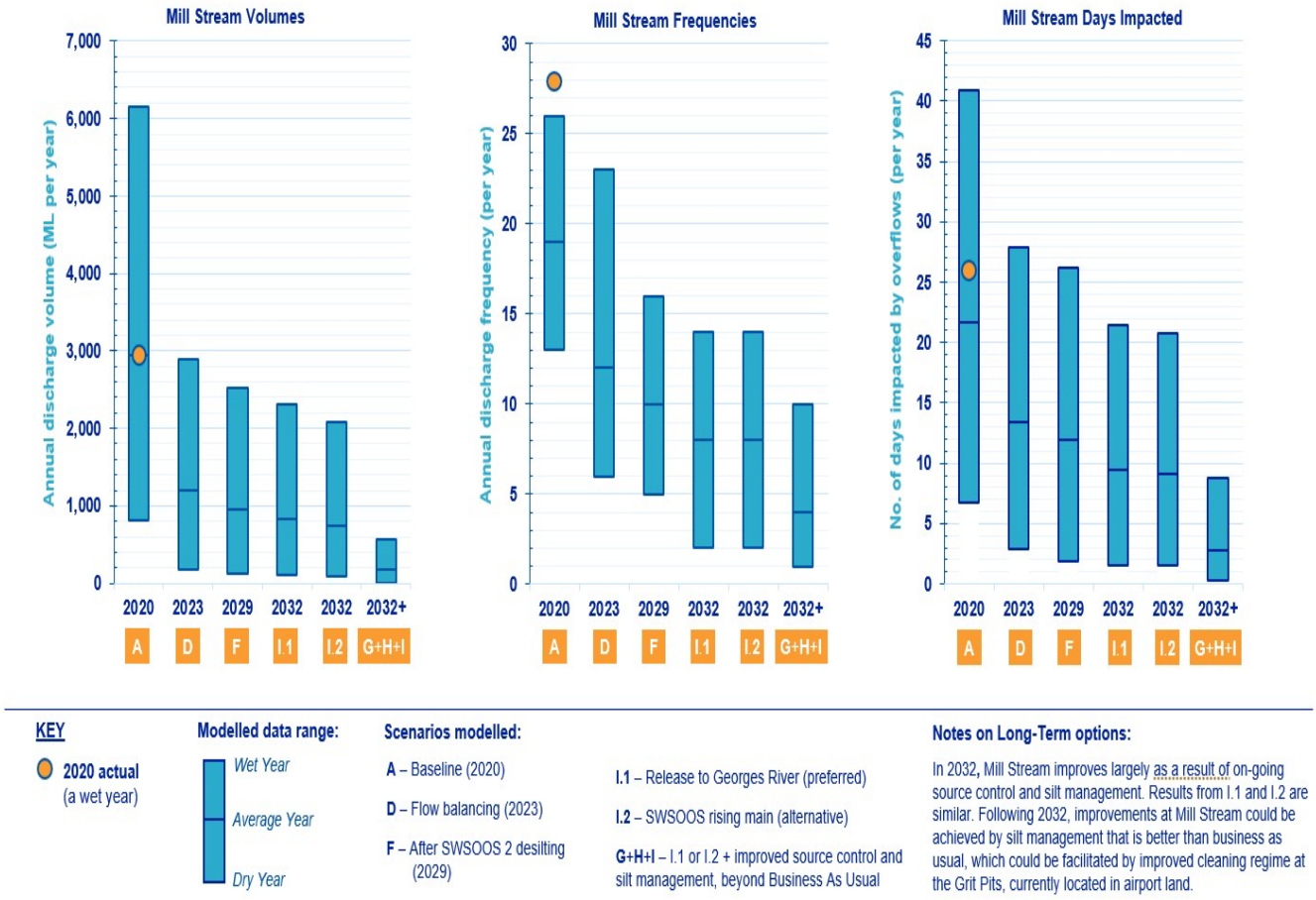


Figure 3 Mill Stream plan on page (2) indicating seasonal variability in performance

2. Hydraulic modelling

The Malabar network model run code (MALHNG) was used for recalibration to assess the performance of the Millstream overflow for the period January 2025 to December 2025.

2.1 Flow Monitoring

A list of flow gauges used are provided in **Table 1**. A location plan of the gauging network is **Figure 4** and schematic diagrams showing the required network are provided in **Figures 5 and 6.**

Table 1 SWSOOS Flow Gauges List

Gauge	Conduit	Data Recorded		
		Level	Velocity	Flow
802310	Southern Division Submain End	Yes		
802065	SWSOOS 1 Syphon Upper leg	Yes		
802001	SWSOOS 1	Yes	Yes	Yes
802051S	SWSOOS 2S	Yes	Yes	Yes
802051N	SWSOOS 2N	Yes	Yes	Yes
802064	SWSOOS 2N upper leg	Yes		
802063	SWSOOS 2S upper leg	Yes		

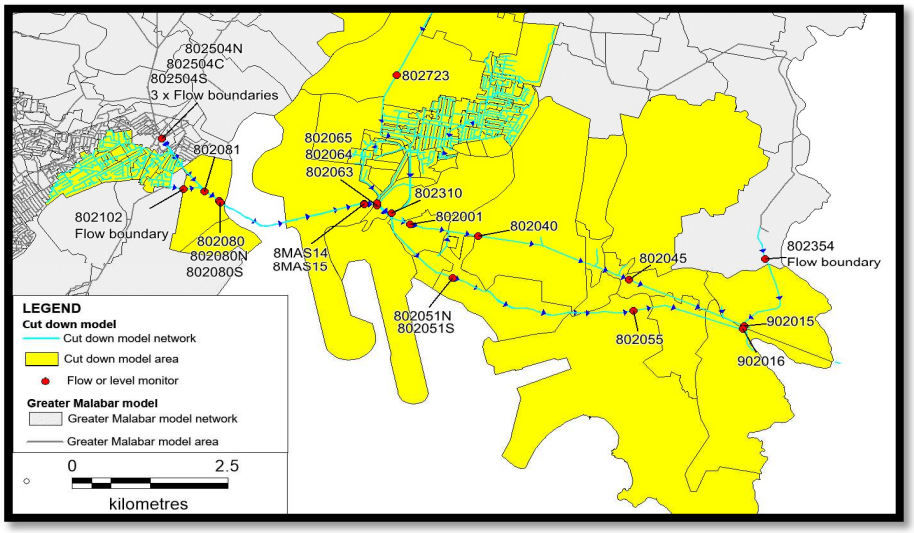


Figure 4 SWSOOS Gauge Location Plan

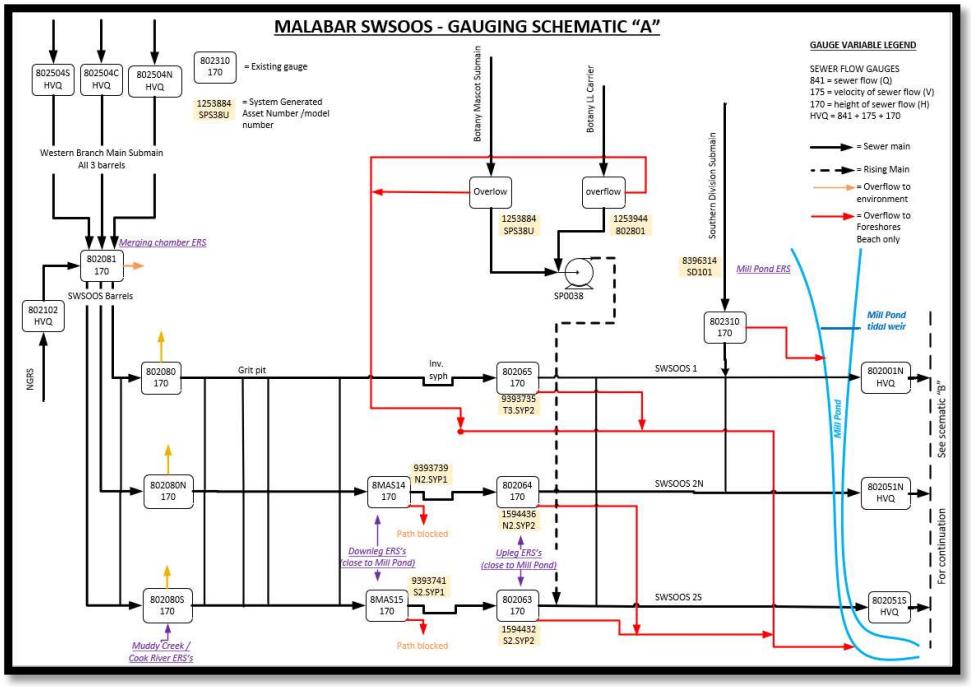


Figure 5 SWSOOS Flow Gauging Schematic A

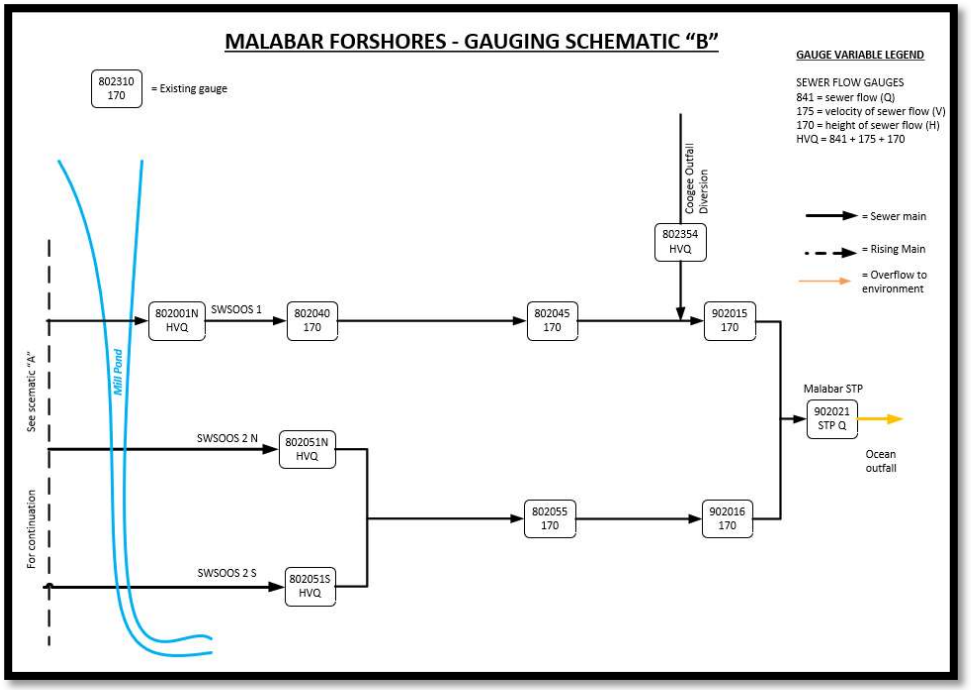


Figure 6 SWSOOS Flow Gauging Schematic B

2.2 Model calibration

The model was calibrated for the period January 2025 to December 2025. The calibration plots are in **Attachments 2 and 3**.

2.3 Calibration Method

The model calibration process has been developed and implemented to meet Environmental Protect Licence (EPL) requirements. The following procedures have been developed for model calibration and technical management review of the model calibration and overflow performance reporting:

- WWNP0007 – Model update, Re-calibration and Annual reporting procedure.
- WWNP0008 – Electronic data file management
- WWNP0009 – Technical Management Review and Decision framework

The model calibration and overflow performance reporting involves the following six steps:

- Step 1 involves reviewing gauge data as well as identification of changes to the system (PRP101.2 3.3.1).
- Step 2 involves identifying significant changes to the system and incorporating them into the model (PRP101.2 3.3.1).
- Step 3 involves testing the updated model for bias using the model validation acceptance criteria (PRP101.1 3.5).
- Step 4 involves defining a recalibration plan identifying the scope of model changes and data required for recalibration (PRP101.2 5.3.2–5.3.3).
- Step 5 involves the model recalibration (PRP101.2 5.3.2–5.3.3)..
- Step 6 involves the model being run using the 10-year rainfall time series from 1985 to 1994, analysis of the results and reported as required by the licence (PRP101.2 5.3.4).

2.4 Hydraulic sewer system model compliance

This section details the compliance of the hydraulic sewer system model with condition L7.1. Further information in **Attachment 5** outlines the performance indicators and acceptance criteria to ensure that the model(s) are appropriately calibrated for accurate reporting.

2.4.1 Quality Management System

The Quality Management System (QMS) is a framework that describes how Sydney Water works by documenting role accountabilities, business processes, policies, and procedures. The QMS defines a standardised way of working across the organisation so teams can

consistently deliver high-quality products and services while reducing duplication and making work easier. It also helps Sydney Water continuously monitor performance and identify opportunities for improvement.

Sydney Water's QMS is certified to ISO 9001 (**Attachment 6**), providing assurance to stakeholders and customers that the organisation can reliably meet its commitments.

The QMS includes key quality elements—captured in processes and procedures—that define the standardised Sydney Water ways of working.



Figure 7 Quality Management System

2.4.2 Quality assurance

To comply with condition L7.1(a) to L7.1(d), Sydney Water implements a quality management system (QMS) certified to ISO 9001:2015 for the hydraulic sewer system modelling processes. Quality assurance includes surveillance audits for select procedures and a technical management review of all models. The hydraulic sewer model being used to predict the overflows for the reticulation system must be adjusted to reflect changes in the real world and recalibrated if significant changes have occurred. The new model is checked for accuracy and classified in accordance with the accuracy achieved.

The hydraulic sewer system model should have no temporal or magnitude bias in either flow volume or water levels at the licence gauges as referenced in the document titled “PRP101.1 System Model Performance Indicators, September 2000” (**Attachment 5**) and subsequent modifications made by the Criteria Review Committee (**Attachment 7).** The model calibration plots are provided **in Attachments 2 and 3** and the Temporal and Magnitude Bias tests (SWGMAN) assessments in **Attachment 4**

Table 2 Model verification using Bias test for Licence Gauges

NO	Gauge ID (Licence)	Sewer/ Overflow (S/OF)	SWAGMAN Compliance						Pass/Fail	Comments
			Depth			Flow				
			R^2	Temporal Bias Acceptable (Y/N)	Magnitude Bias Acceptable (Y/N)	R^2	Temporal Bias Acceptable (Y/N)	Magnitude Bias Acceptable (Y/N)		
1	802001	S	0.87	Y	Y	0.82	Y	Y	Pass	The DW Temporal Bias was due to the silt build up in the SWSOOS2 Barrels.
2	802051N	S	0.86	Y	Y	0.85	Y	Y	Pass	
3	802051S	S	0.86	Y	Y	0.83	Y	Y	Pass	
4	802310	S	0.86	Y	Y	-	Level only	-	Pass	
Long Term Gauges										
5	802063	S/OF	0.88	Y	Y		Level only		Pass	
6	802064	S/OF	0.86	Y	Y		Level only		Pass	
7	802065	S/OF	0.87	Y	Y		Levels only		Pass	

Table 3 Model verification using Additional Gauges

Additional Gauges									
Licence - OF Gauges SWAGMAN Compliance									
		Initial Test				Sensitivity Teat			Comments
No	OF Gauge	Lower Depth (m)	Upper Depth (m)	Weir Crest Depth(m)	Overflow Index	Weir Crest Depth(m)	Overflow Index	WC Lowering by (mm)	
1	802310	1.00	1.60	1.20	1.000				Sensitivity Test was not performed as the predicted Overflow Index at the Weir Crest is beyond expectation.
2	802063	1.40	2.20	1.70	0.913				
3	802064	1.40	2.20	1.70	0.957				
4	802065	1.00	1.60	1.30	1.000				

2.4.3 Technical management review

A technical management review is conducted to ensure the model is developed in accordance with the modelling procedures and that the model meets minimum quality requirements stipulated in the quality system. Refer **Attachment 1** for technical management review conducted for the Millstream overflow performance reporting model.

Millstream Overflow Performance

The performance of the Millstream overflows is represented by the number of wet weather overflows per 10 years by the sewer hydraulic model and compared to 2021 “benchmark” year. A schematic representation of the modelling development and testing process for the Millstream overflows is included in **Figure 8**.

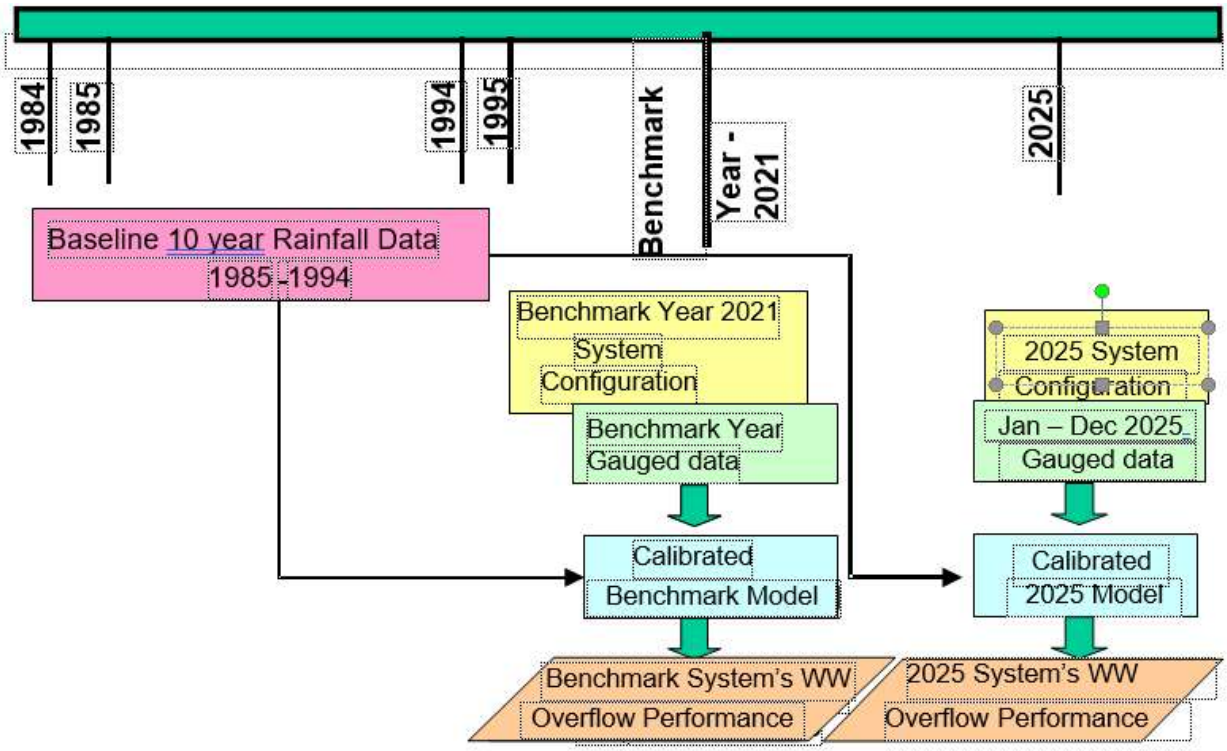


Figure 8 Comparison of Overflow Performance between Bench mark (2021) and 2025

The baseline set in the March 2021 authorisation under the Airports (Environment Protection) Regulation (AEPR) 1997, issued by the Department of Infrastructure, Transport, Regional Development and Communications (DITRC) is overflow frequency/year of 19 and overflow volume of 3094 ML/year.

The following short-term options are currently in progress in the period January 2025 to Dec 2025:

1. De-silting of SWSOOS 2
2. Source control work.
3. Wastewater screening

The recalibrated model was simulated using the rainfall time series 1985 to 1994 used for Environmental Protection Licence (EPL). **Table 4** provides the comparison of the overflow performance of all 8 Emergency Relief Structures (ERS) discharging into Millstream against the 2021 baseline.

Table 4 Millstream overflow performance comparison between Baseline and 2025

Overflow Location	Conduit	Baseline (2021)		2025 (Jan -Dec 2025) Performance	
		Frequency/year	Volume (ML/Year)	Frequency	Volume (ML/Year)
N2.SYP1	SWSOOS 2N (Syphon Upper leg)	7	0.2	7	0.2
S2.SYP1	SWSOOS 2S (Syphon Upper leg)	9	0.3	9	0.3
T3.SYP2	SWSOOS 1	18	771	13	76.9
N2.SYP2	SWSOOS 2N (Syphon Lower leg)	7	119	12	306.1
S2.SYP2	SWSOOS 2S (Syphon Lower leg)	8	133	12	335.0
SD101	Southern Branch weir	19	34	13	5.8
SD101	Southern Brach Syphon	16	2037	10	514.3
SPS38U	Botany Low Level Carrier	0	0	0	0
802801	Botany Mascot Submain	0	0	0	0
Total		**19**	**3094**	**13**	**1238**

Attachment 1 Technical Management Review 2025 Botany Catchment

Technical Management Review 2025 Botany Catchment (PALMS Malabar STS Model)

Review Information for the Year 2025 Malabar STS Model (PALMS Botany Catchment):	
Benchmark Year:	Malabar (2021)
Last Available Review:	Malabar TMR 2021
Curent Acceptance Status :	Conforming ~~/ Non-Conforming~~
Number of outstanding OI & PARS:	04
Modeller in Charge	Mahmood Hossain
Project Manager	Milroy Jayaveerasingam
Assignement Manager	Milroy Jayaveerasingam
TMR Reveiner	Jovan Titus

Review Dates				
Section A-C	09/01/2026	Accepted: YES~~/ NO~~	Completed:	12/01/2026
Section D1	09/01/2026	Accepted: YES~~/ NO~~	Completed:	12/01/2026
Section D2	12/01/2026	Accepted: YES / ~~NO~~	Completed:	12/01/2026
Section E	12/01/2026	Accepted: YES / ~~NO~~	Completed:	12/01/2026
Section F	12/01/2026	Accepted: YES / ~~NO~~	Completed:	12/01/2026

Review Summary- Year 2025

- Has the Model been re-calibrated in accordance with “Good Modelling Practice”: YES / ~~NO~~
- Has the Model been found to be suitable for reporting purposes: YES / ~~NO~~
- Is the current model compatible with the benchmark model: YES / ~~NO~~

  If No, specify proposed alternative benchmark year: XXXX
- Number of PARs / OIs issued 04
- Has been given the acceptance status of:
  - Conforming
  - ~~Non-Conforming~~

Reviewer: **Jovan Titus** **Date:** **09/01/2026**

Are you, the Project Manager, satisfied the conclusions drawn from the technical review are an accurate description of the Year 2025 status of the Botany Catchment, of Malabar STS Model (Palms).

Project Manager: **Milroy Jayaveerasingakm** **Date:** **13/01/2026**

Review Section A- Improvement Options & Outstanding PAR Compliance

(Section F of the year 2021 Review) ***Refer the Section F for model improvement suggestion for the Future.***

OI: Opportunity for Improvement

Improvement Option	Justification	PAR No.	Already Resolved (Y/N)

Comments

Review Section B- Model Update & Good Modelling Practice:

Review Objective	Check (Y/N/OI)	Comments	New PAR No.
Project Co-ordination Folder:			
- is it available	Y	Maintain electronically	
- does it contain the appropriate sections	Y	Folder location - R:\WWDIH\PALMS\STS\Malabar	
Archiving:			
- is the filing system for hardcopies appropriate	NA	Maintaining electronically	
- is the filing system for electronic items appropriate	Y	R:\WWDIH\PALMS\STS\Malabar	
- is the log sheet updated as appropriate	Y		
Model Update:			
- property Id file available for the system	Y	BY_Property_2025	
- evidence of residential “Zero” water consumption filled in with average residential water consumption.	Y		
- have population data been updated	Y	281,308 (2024)	
- have rainfall data been updated	Y	Data Base : MA24-25	
- MapInfo file created for current rain gauges	Y	Table : C_BY_RG_2024	
- has gauge information been updated	Y		
- MapInfo file created for current sewer gauges	Y	Table: C_BY_FM_2024	
- have operators been consulted to identify asset changes	Y	Correspondence/meetings	
- have changes to asset data been updated	Y	Detailed model build using latest HYDRA data	

- will there be chances that the model update will influence the overflow performance of the system?	Y	Detail model has included all overflows	
Additional Information:			
- have all available Trunk gauges been identified	Y		
- is the Trunk gauge coverage adequate	Y		
- is there a need to adopt additional Trunk gauges	Y		
- is there a need to include SCAMP gauges	OI		
- does this system require flow monitor rationalisation for future modelling?	Y	Refer the Strategic Sewer Gauge Review Report 2021	
Model Checks:			
- is the model coverage adequate	OI	May need to add SCAMP Catchments for the future modelling.	
- is the level of catchment delineation adequate	Y		
- does model geometry match actual system geometry	Y		
- have catchment load points been checked	Y		
- have all trunk overflows been included	Y		
- has the use of reticulation overflows been justified	OI	Retic Overflows could be avoided by adding detailed SCAMP models wherever required.	
- have all operational issues been resolved	Y		

Review Section C- Additional Reviewer Recommendations:

*__Note:__ S Rating: serious implications for model and /or calibration accuracy,
M Rating: minor issue with limited implication on model and /or calibration accuracy

Recommendation	Rating(S/M)*	Justification	New PAR No.	Date Resolved

Review Section A-C Summary:

- Have all outstanding PARs been resolved? YES ~~/ NO~~
- Has the Modeller followed “Good Modelling Practices”? YES ~~/ NO~~
- Have additional OI/PARs been raised in Review Sections B & C? ~~YES~~ / NO

Reviewer: **Jovan Titus** **Date:** **09/01/2026**

Project Manager: **Milroy Jayaveerasingam** **Date:** **13/01/2026**

Review Section D1- Initial Model Validation: (Refer Section D2 for Calibration Review Information)

SWAGMAN Verification:

- Has the Year 2025 Botany Catchment (PALMS) Malabar STS model been updated in accordance with procedures? YES / ~~NO~~
- List number of Licensed/Long Term Gauges (Gauges in the extended model area only):

NO	Gauge ID (Licence)	Sewer/ Overflow (S/OF)	SWAGMAN Compliance						Pass/Fail	Comments
			Depth			Flow				
			R^2	Temporal Bias Acceptable (Y/N)	Magnitude Bias Acceptable (Y/N)	R^2	Temporal Bias Acceptable (Y/N)	Magnitude Bias Acceptable (Y/N)		
1	802001	S	0.87	Y	Y	0.82	Y	Y	Pass	The DW Temporal Bias on Level was due to the silt build up in the SWSOOS2 Barrels.
2	802051N	S	0.86	Y	Y	0.85	Y	Y	Pass	
3	802051S	S	0.86	Y	Y	0.83	Y	Y	Pass	
4	802310	S	0.86	Y	Y	-	Level only	-	Pass	
Long Term Gauges										
5	802063	S/OF	0.88	Y	Y	-	Level only	-	Pass	The DW Temporal Bias on Level was due to the silt build up in the SWSOOS2 Barrels.
6	802064	S/OF	0.86	Y	Y	-	Level only	-	Pass	
7	802065	S/OF	0.87	Y	Y	-	Levels only	-	Pass	

Additional Gauges									
				Licence - OF Gauges SWAGMAN Compliance					
No	OF Gauge	Initial Test				Sensitivity Teat			Comments
		Lower Depth (m)	Upper Depth (m)	Weir Crest Depth(m)	Overflow Index	Weir Crest Depth(m)	Overflow Index	WC Lowering by (mm)	
1	802310	1.00	1.60	1.20	1.000				Sensitivity Test was not performed as the predicted Overflow Index at the Weir Crest is beyond expectation.
2	802063	1.40	2.20	1.70	0.913				
3	802064	1.40	2.20	1.70	0.957				
4	802065	1.00	1.60	1.30	1.000				

Lower depth = depth from pipe IL to PDWF * Cannot be determined; # sites are possibly silt effected

Upper Depth = depth range from pipe IL to between WC and PWWF

WC Depth – depth from pip IL to WC

Gauge Compliance:

- No. Licensed Sewer Gauges: 3 (Only the HVQ Gauges on the SWSOOS Mains were considered)
- No. of Compliant Licensed Sewer Gauges: 3 % Compliance: 100%
- No. of Licensed Overflow Gauges: 4
- No. of Compliant Licensed Overflow Gauges: 4 % Compliance: 100%

Model Acceptance:

- Conforming Model (>75% pass for Licensed Sewer Gauges)

- ~~Non-Conforming Model (<75% pass for Licensed Sewer Gauges)~~

Year 2025 Botany STS Model Status:

- Does Updated Per Capacity Contribution Comply with “GMP”? YES / ~~NO~~
- Does Updated Average Return Factors “GMP”? YES / ~~NO~~
- Is Re-calibration of the Model Required? YES / ~~NO~~ (This model requires Review and Re-Calibration annually)
- If Yes (proceed to section D2), has a Re-calibration Plan been Developed? YES / ~~NO~~

Reviewer: **Jovan Titus** **Date: 09/01/2026**

- If No (proceed to section E), is the Modeller Advised to do Reporting? ~~YES~~ / NO

Project Manager: **Milroy Jayaveerasingam** **Date: 13/01/2026**

Review Section D2- Model Calibration Check & Model Validation:

Calibration & Verification Periods:			
Event ID	**Start Date**	**Stop Date**	**Duration**
Dry Weather Period 1	24/02/2025	03/03/2025	7 Days
Dry Weather Period 2	29/09/2025	05/10/2025	7 Days
Dry Weather Period 3	09/07/2025	16/07/2025	7 Days
Duration of wet event 1	25/07/2025	31/08/2025	37 days (Three Rain Periods covered)
Duration of wet event 2	16/03/2025	11/04/2025	26 days (Three Rain Periods covered)
Duration of wet event 3	24/01/2025	16/03/2025	51 days (Three Rain Periods covered)
SWAGMAN Verification Period	01/01/2025	10/11/2025	10 Months
10-year Time Series Period	01/01/1985	31/12/1995	10 Years

Dry Weather Calibration:	**Check (Y/N/OI)**	**New PAR No.**	**Comments**
- is the available gauge information sufficient for model calibration	Y		
- are the chosen calibration periods suitable for model calibration	Y		3 Dry weeks
if no, specify alternative period(s)			
- has the dry weather calibration procedure been followed	Y		
- are per capita contributions justified	Y		System Avg 214 L/EP/day
- are return factors justified	Y		Catchments in the Randwick and Maroubra area has higher ARF, Needed Review

- are baseflow contributions justified	Y		Average BF 14.9%
- are bed roughness values justified	Y		Lower Manning Numbers were used in SWSOOSs to reflect the Siltation. (Needed de-Silting)
- are peak velocities justified	Y		
- are visual calibration results acceptable	Y		Dry Weather Model Levels are Low and were accepted taking into the account of severe Siltation that the SWSOOS 2 Barrels are experiencing.
- have DWF calibration plots been made available for review	Y		
- have DWF calibration plots been signed and filed in folder	NA		Maintain electronically
- have DWF calibration plots soft copies available in server	Y		P:\Mill Stream_Overflow Assessment\2025_Botany/Calibration Plots _ DW _ Botany Bay Catchment 2025
Wet Weather Calibration:			
- is the available gauge information sufficient for model calibration	Y		
- are the chosen calibration periods suitable for model calibration	Y		
if no, specify alternative period(s)			
- has the wet weather calibration procedure been followed	Y		
- are wet weather parameters justified	Y		
- are top roughness values justified	Y		Justified on the basis of the siltation issue that the SWSOOS2 Barrels are experiencing.
- are peak velocities justified	Y		
- are visual calibration results acceptable	Y		Wet weather Flow and Levels are in good calibration with the Measured records.
- have WWF calibration plots been made available for review	Y		
- have WWF calibration plots been signed and filed in folder	Y		Maintaining electronically.

- have WWF calibration plots soft copies available in the server	Y		P:\Mill Stream_Overflow Assessment\2025_Botany/Calibration Plots _ WW _ Botany Bay Catchment 2025
- has the procedure for time series modelling been followed	Y		
- are changes in overflow frequencies justified	Y		

Review Section D2- Model Re-Calibration & Model Validation:

Review Objective	Check (Y/N/OI)	New PAR No.	Comments
SWAGMAN Analysis:			
- is the available gauge information sufficient for model validation	Y		
- has the entire data period been used for model validation	Y		
if no, justify omissions			
- has the SWAGMAN verification procedure been followed	Y		
- have SWAGMAN verification plots been made available for review	Y		Maintaining electronically
- have SWAGMAN verification plots been signed and filed in folder	Y		P:\Mill Stream_Overflow Assessment\2025_Botany\Pre_Calibration\SWAGMAN/Swagman Model Report NA_Pre-Calibration.doc
Model Status:			
- have all catchment issues been resolved	Y		
- have all population data issues been resolved	Y		
- have all system geometry issues been resolved	Y		

- have all overflow information issues been resolved	Y		
- have all other asset information issues been resolved	Y		
- have all operational issues been resolved	Y		
- have all rainfall data issues been resolved	Y		
- have all gauge issues been resolved	N/A		
- have all issues identified in Section – C been addressed	N/A		
System Status – Year 2021 (last Re-Calibrated Year) to 2025 Comparison:			
- can model updates be rated as significant	Y		The Cross Connection 1 and 2 (Between SWSOOS1 and SWSOOS2) were removed
- can changes to model parameters be rated as significant	N		
- can signs of system deterioration be rated as significant	Y		
- can changes in overflow volumes be rated as significant	N		Overflow volume changed about 1%
-can changes in individual overflow frequency rated as significant	N		
- in case of overflow frequency of individual overflow change by more than 5-10%, this has to be discussed with the Project Manager. Evidence of such discussion sighted	N/A		
- is current benchmark year still applicable	Y		

Statistics for Year 2021/2025 STS Model Palms (Botany Catchment) Malabar Update: (compare benchmark year and current year)

Population (2021/2025):	278,118 / 281,308	% change:	+1.15% (But the DW Flow decreased by 2.2%, 1106.2 l/s to 1082.7 l/s)
Catchment Area (2021/2025):	7,111 / 7,111 ha	% change:	0.0%
Sewer Length (2021/2025):	179 / 179 km	% change:	0.0%
No. Constructed Overflows (2021/2025):	47 / 47	% change:	0.0 %
No. Reticulation Overflows (2021/2025):	7 / 7	% change:	0.0 %
No. Pump Stations (2021/2025):	4 / 4	% change:	0.0 %

Review Section D2 Summary:

- Has correct calibration and verification procedures been followed? YES /~~NO~~
- Have additional OI/PARs been raised in Review Section D2? ~~YES~~ / NO

Review Section D2 – Model Re-Calibration & Model Validation:

Gauge Compliance : Refer the Table D1 for SWAGMAN Assissent Outcome.

NO	Gauge ID (Licence)	Sewer/ Overflow (S/OF)	SWAGMAN Compliance						Pass/Fail	Comments
			Depth			Flow				
			R^2	Temporal Bias Acceptable (Y/N)	Magnitude Bias Acceptable (Y/N)	R^2	Temporal Bias Acceptable (Y/N)	Magnitude Bias Acceptable (Y/N)		
1	802001	S								
2	802051N	S								
3	802051S	S								
4	802310	S								
Long Term Gauges										
5	802063	S/OF								
6	802064	S/OF								
7	802065	S/OF								

Additional Gauges									
Licence - OF Gauges SWAGMAN Compliance									
		Initial Test				Sensitivity Teat			Comments
No	OF Gauge	Lower Depth (m)	Upper Depth (m)	Weir Crest Depth(m)	Overflow Index	Weir Crest Depth(m)	Overflow Index	WC Lowering by (mm)	
1	802310			1.20					
2	802063			1.70					
3	802064			1.70					
4	802065			1.30					

- No. of Licensed Sewer Gauges: 3
- No. of Compliant Licensed Sewer Gauges: 3 % Compliance: 100%
- No. of Licensed Overflow Gauges: 4
- No. of Compliant Licensed Overflow Gauges: 4 % Compliance: 100%
- No. of Additional Gauges: N/A
- No. of Compliant Additional Gauges: N/A % Compliance: N/A

Model Acceptance:

- Conforming Model (>75% pass for Licensed Sewer Gauges)
- ~~Non-Conforming Model~~ ~~(<75% pass for Licensed Sewer Gauges)~~

Benchmark Status:

- Is the Current Benchmark Year is still Applicable: YES / ~~NO~~

If No, specify recommended alternative benchmark year: XXXX

- Is the modeller advised to proceed to reporting? YES ~~/ NO~~
  (not applicable for year 2001 model reviews)

Reviewer: **Jovan Titus** **Date:** **12/01/2026**

Project Manager: **Milroy Jayaveerasingam** **Date:** **13/01/2026**

Review Section E - Reporting:

Review Objective	Check (Y/N/OI)	New PAR No.	Comments
Have model verifications been completed	Y		
Have Load Based License Inputs been completed	N/A		
Has the EPA Summary Report been completed	N/A		
Have all files been archived appropriately	Y		P:\Mill Stream_Overflow Assessment\2025_Botany R:\WWDIH\PALMS\STS\Malabar
Has the CIM Report been completed	N/A		

Review Section E Summary:

- Has the Year 2025 reporting been finalised? YES ~~/ NO~~
- Have additional OI/PARs been raised in Review Section E? ~~YES /~~ NO

Reviewer: **Jovan Titus** **Date:** **12/01/2026**

Project Manager: **Milroy Jayaveerasingam** **Date:** **13/01/2026**

Section F- Improvement Options & outstanding PARs to be carried forward to 2026.

Improvement Option	Justification	PAR No.	Already Resolved (Y/N)
Extend the Model to accommodate the Missing SCAMP Catchments, thus removing the Reticulation Overflows from the Model.	Actual Model Representation	OI	N
De-Silting in SWOOS2 Barrels is strongly recommended.	Regain the hydraulic Capacity lost in the SWSOOS2	OI	N
Re-Calibrate the Model after the de-silting is completed.	Reliability in System Capacity and confidence in system performance.	OI	N
Reliable Gauging performance. Ie Reduction in Missing gauge data during Wet Weather, especially the Gauges 802102 (NGRS) and 802504N,C,S (Western Main Sewer, Three Barrels) which are used as Boundary Condition flows for the Botany catchment Model Calibration.	Quality / More data for Model Calibration and Validation	OI	N

Review Section F Summary:

- Does the Year 2025 Model Re-Calibration comply with "Good Modelling Practices"? YES / ~~NO~~
- Does this conclude the Year 2025 Model Verification? YES / ~~NO~~

This concludes the Year 2025 Technical Management Review. Any outstanding issues are to be carried forward and resolved as part of the Year 2026 Model Re-calibration.





Reviewer: **Jovan Titus** **Date: 12/01/2026** **Project Manager:** **Milroy Jayaveerasingam** **Date: 13/01/2026**

Attachment 2 Calibration Plots – Dry Weather Flow

Calibration Plots **Botany Bay Catchment _ Malabar System 2025**

Dry Weather Events:

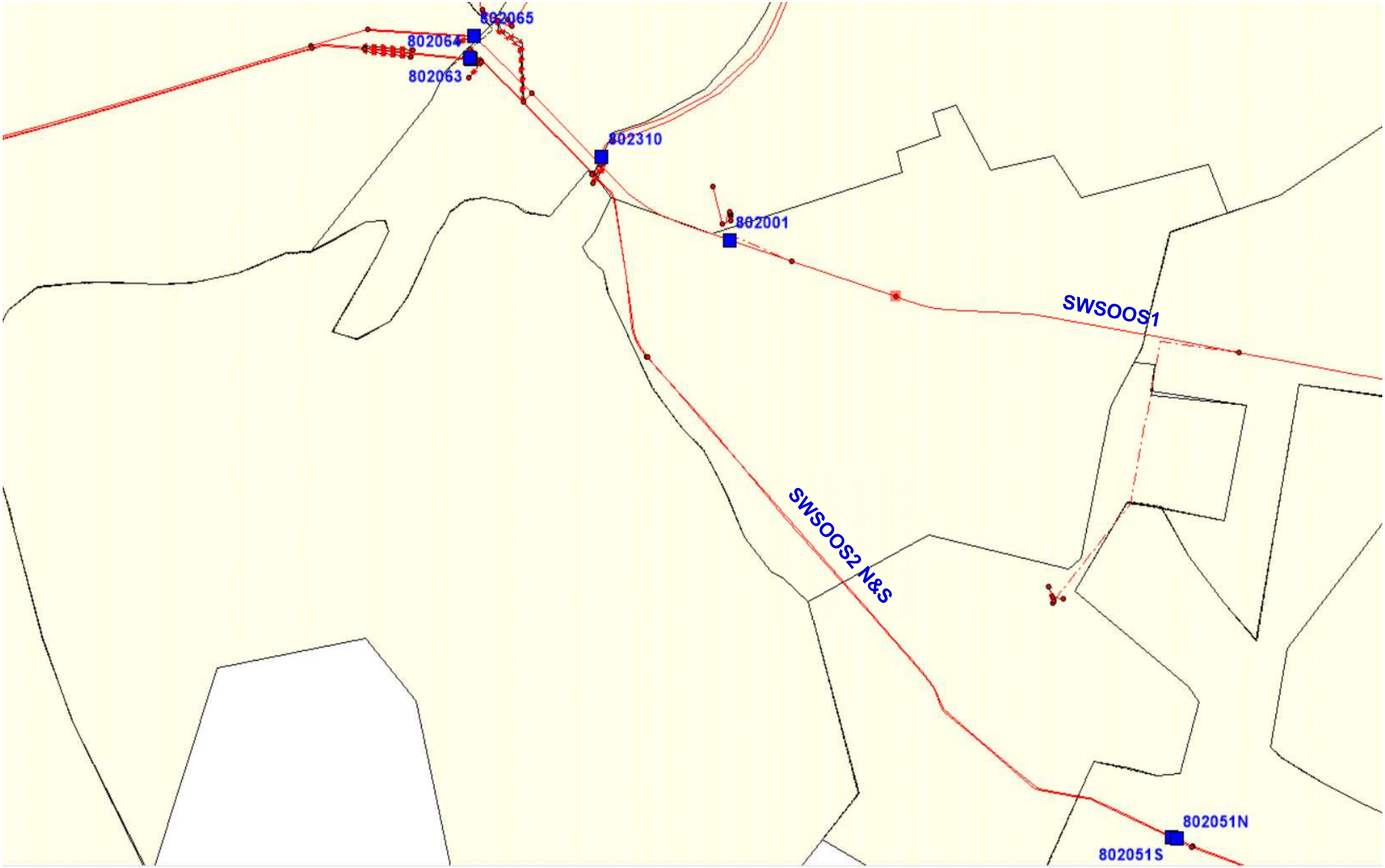
Dry Week 1 : 24/02 - 03/03/2025

Dry Week 2 : 29/09 – 05/10/2025

Dry Week 3 : 09 – 16 / 07 / 2025

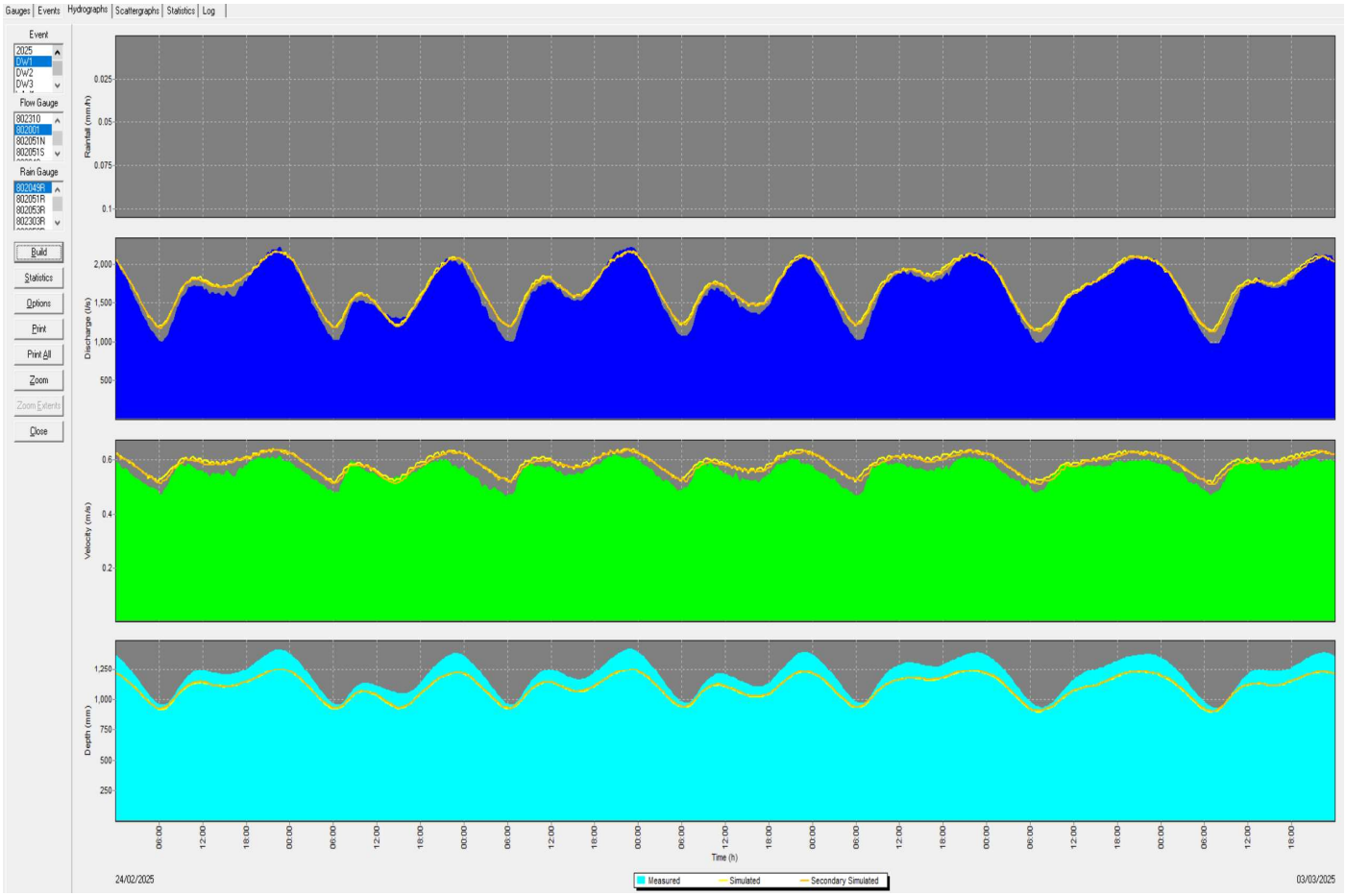
Gauges Assessed:

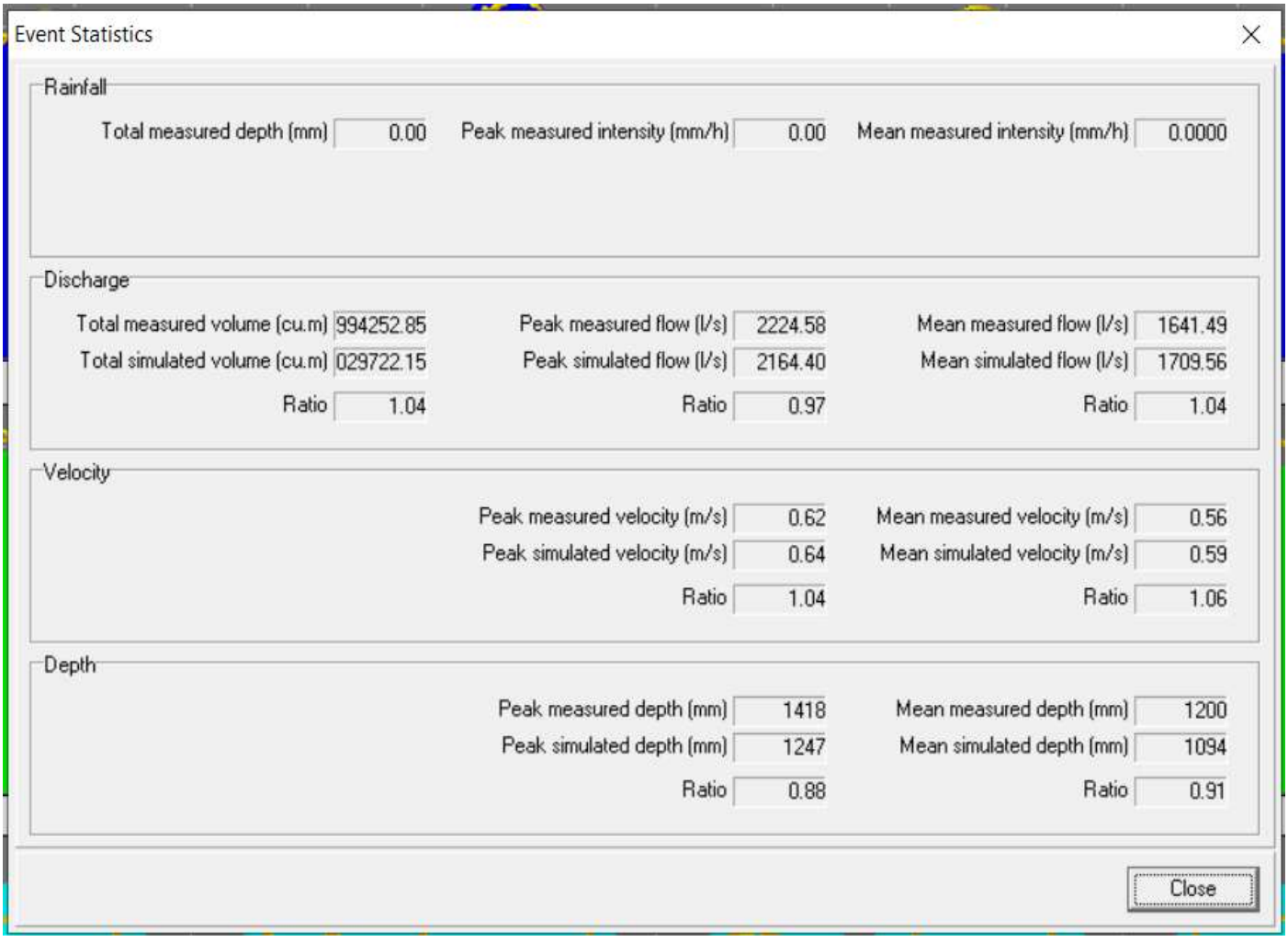
Gauge	Comment
802001	SWSOOS 1, HVQ Licence Gauge
802051N	SWSOOS2 N, HVQ Licence Gauge
802051S	SWSOOS2 S, HVQ Licence Gauge
802063	SWSOOS 2S (S2.SYP2), Level Only, Licence Gauge
802064	SWSOOS 2N (N2.SYP2), Level Only, Licence Gauge
802065	SWSOOS 1 (T3.SYP2), Level Only, Licence Gauge
802310	Southern Division Sewer, Level Only, Licence Gauge



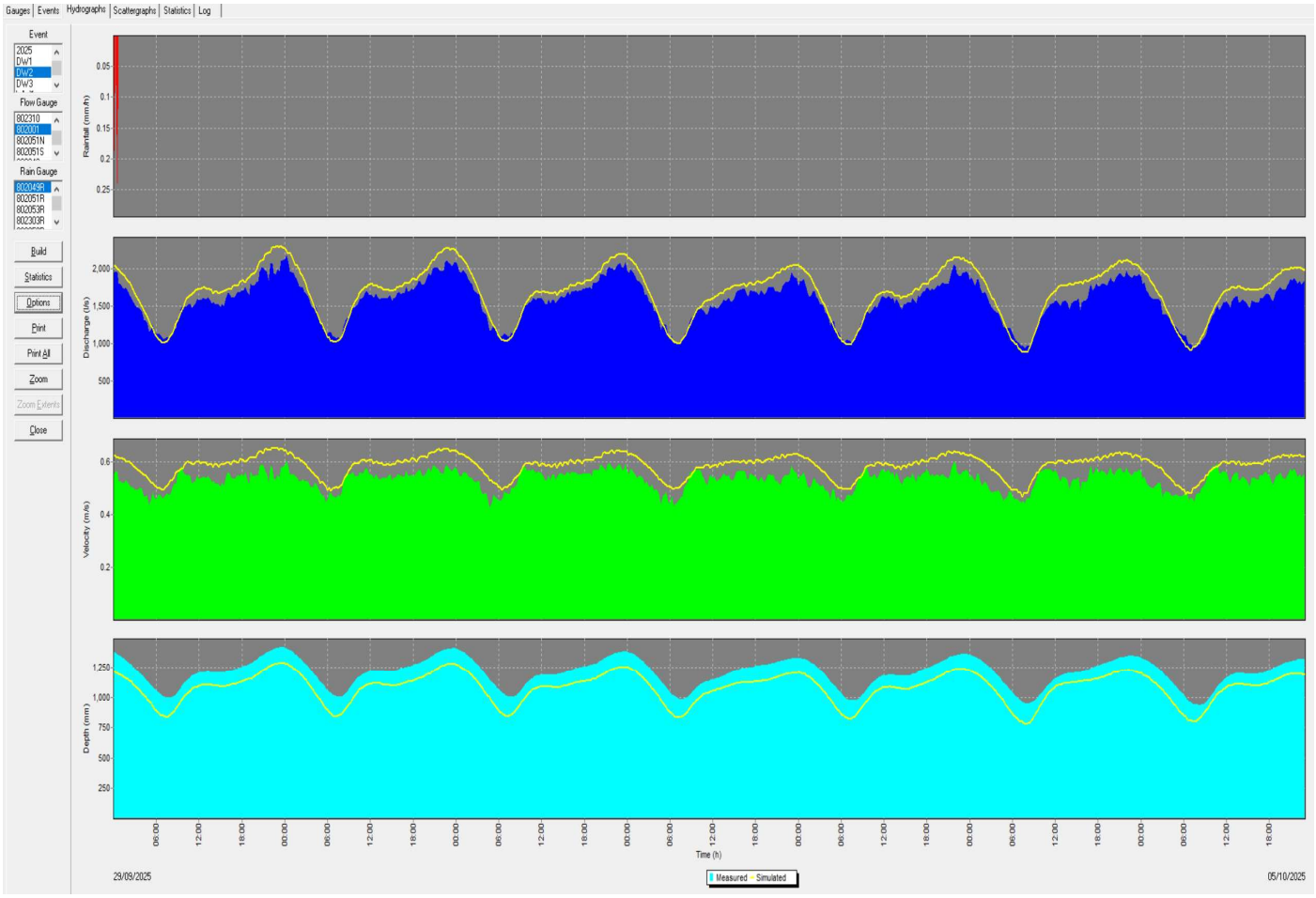
Sewer Gauge Layout – Botany Bay Catchment

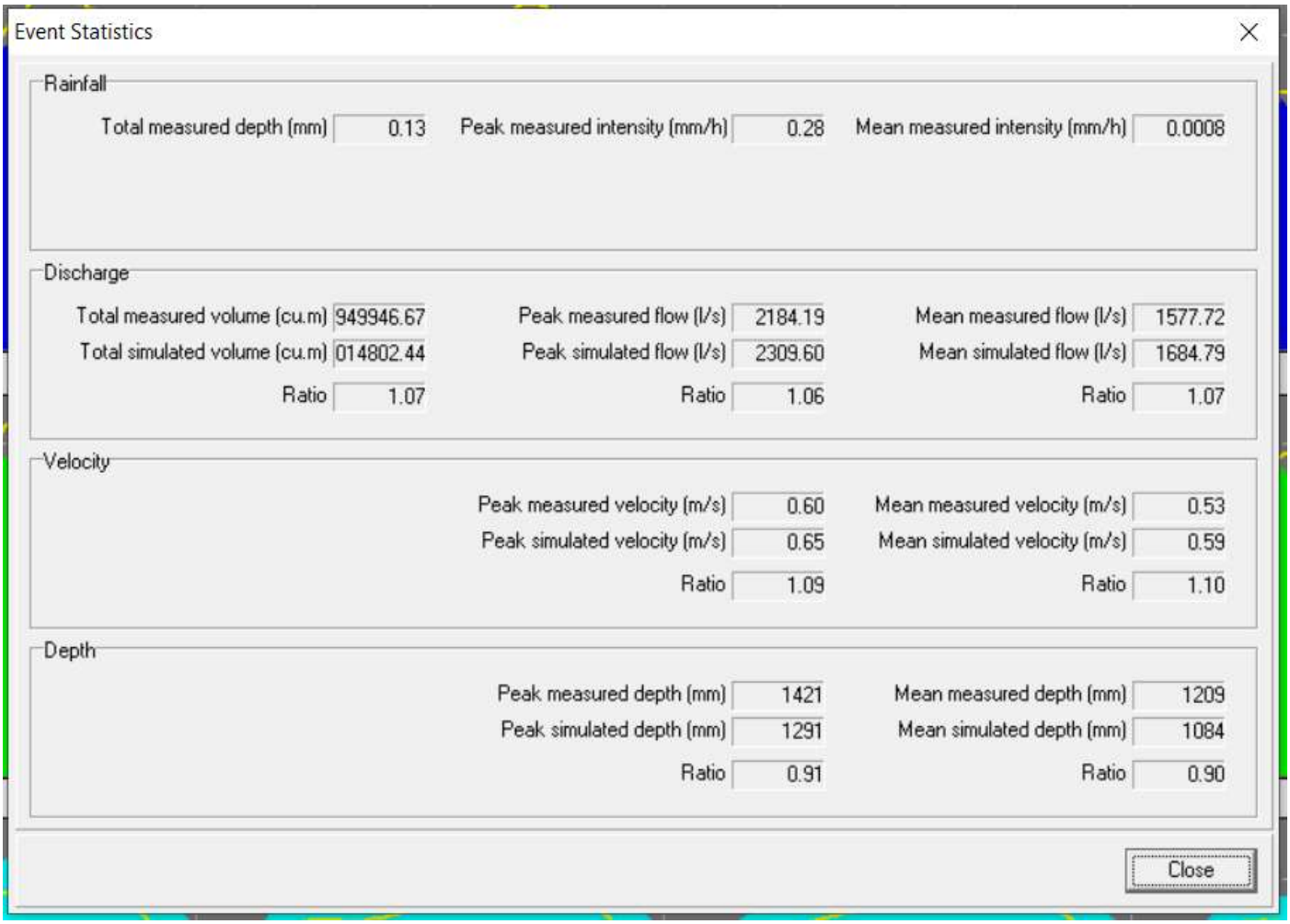
802001 DW1


Gauges | Events | Hydrographs | Scattergraphs | Statistics | Log
Event
2025
DW1
DW2
DW3
Flow Gauge
802310
802001
802051N
802051S
Rain Gauge
802045R
802051R
802053R
802303R
Build
Statistics
Options
Print
Print All
Zoom
Zoom Extents
Close
Rainfall (mm/h)
Discharge (l/s)
Velocity (m/s)
Depth (mm)
Time (h)
24/02/2025
03/03/2025
Measured
Simulated
Secondary Simulated

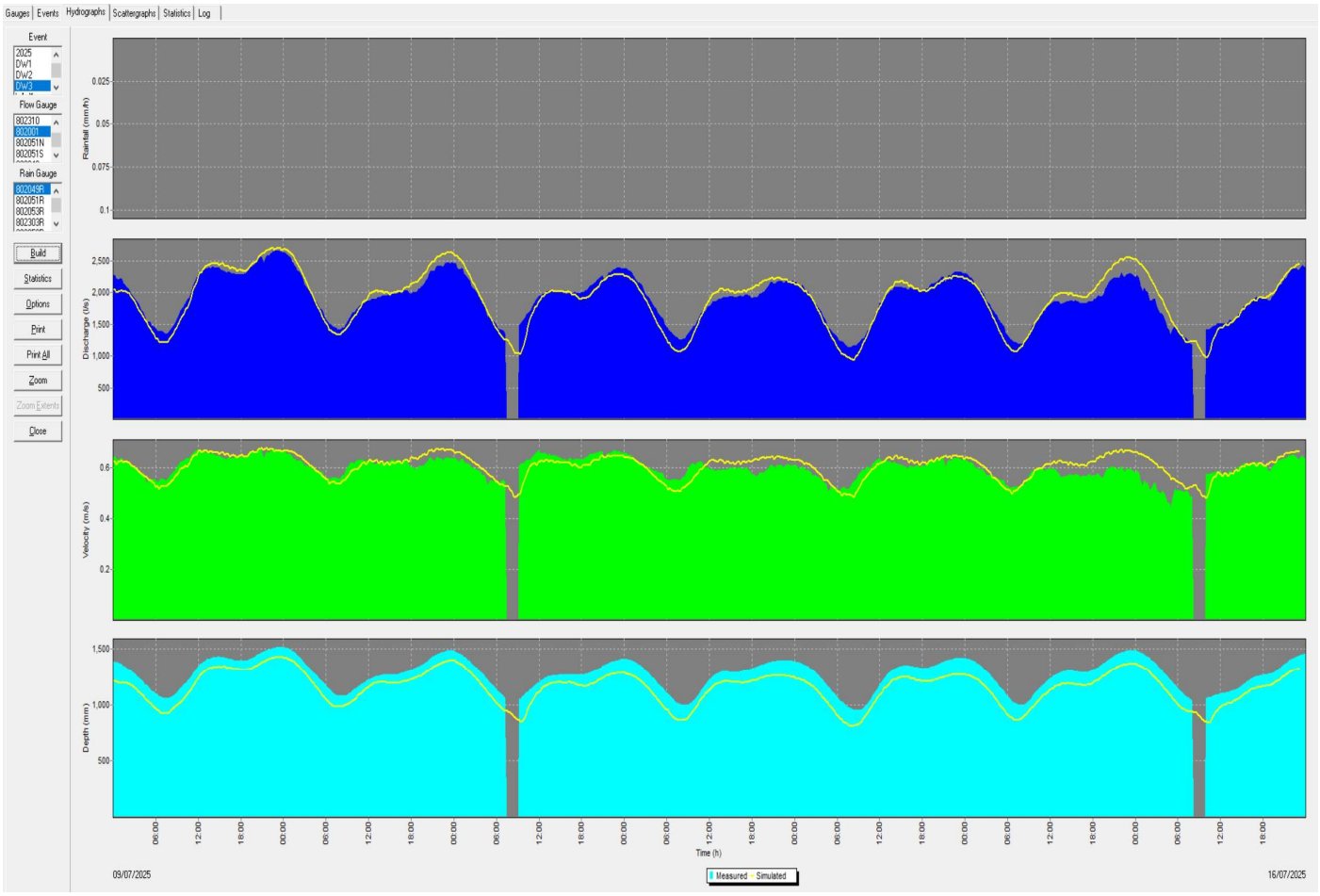

Event Statistics
Rainfall
Total measured depth (mm) 0.00
Peak measured intensity (mm/h) 0.00
Mean measured intensity (mm/h) 0.0000
Discharge
Total measured volume (cu.m) 994252.85
Peak measured flow (l/s) 2224.58
Mean measured flow (l/s) 1641.49
Total simulated volume (cu.m) 029722.15
Peak simulated flow (l/s) 2164.40
Mean simulated flow (l/s) 1709.56
Ratio 1.04
Ratio 0.97
Ratio 1.04
Velocity
Peak measured velocity (m/s) 0.62
Mean measured velocity (m/s) 0.56
Peak simulated velocity (m/s) 0.64
Mean simulated velocity (m/s) 0.59
Ratio 1.04
Ratio 1.06
Depth
Peak measured depth (mm) 1418
Mean measured depth (mm) 1200
Peak simulated depth (mm) 1247
Mean simulated depth (mm) 1094
Ratio 0.88
Ratio 0.91
Close

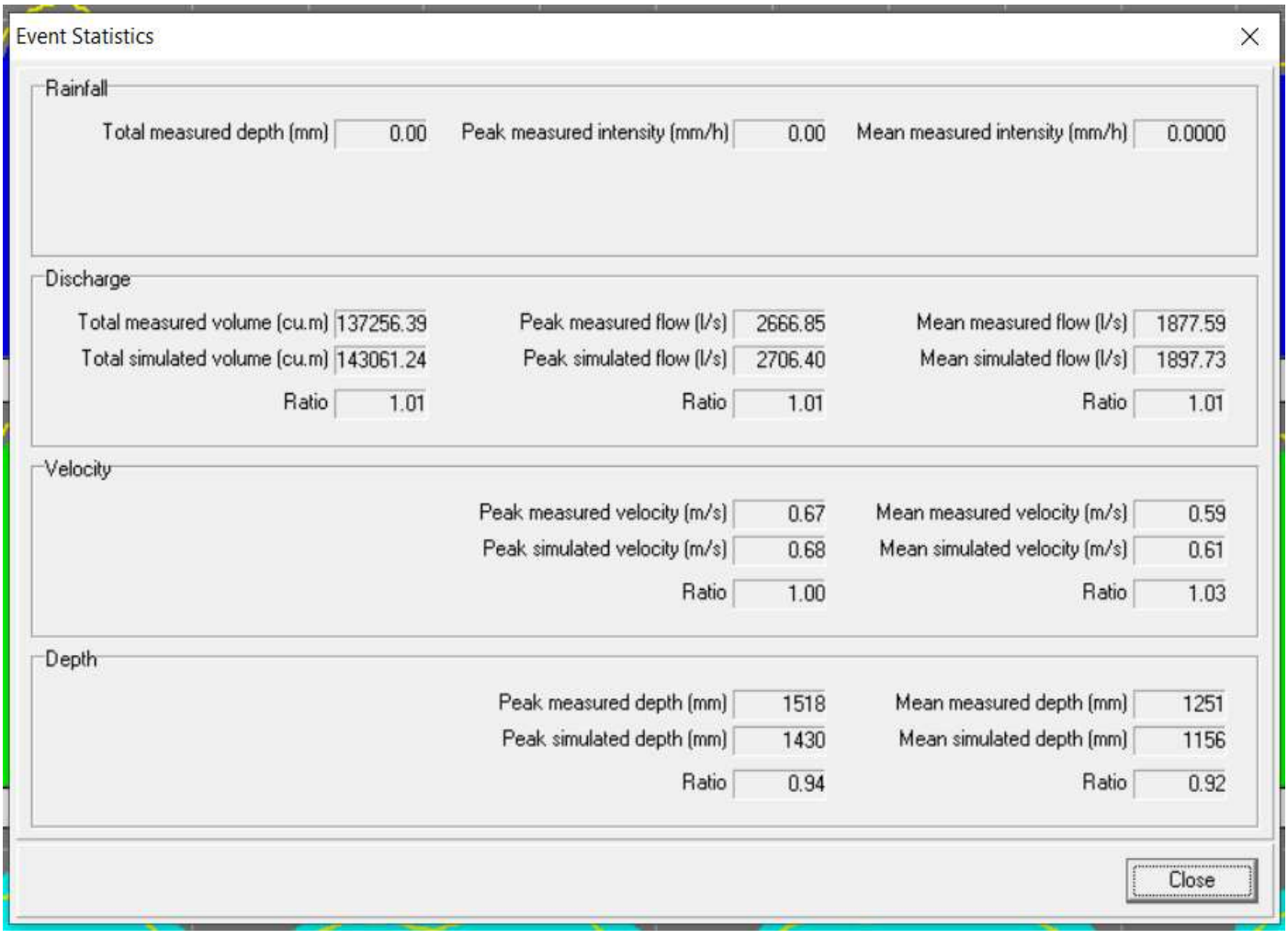
802001 DW2


Gauges | Events | Hydrographs | Scattergraphs | Statistics | Log
Event
2025
DW1
DW2
DW3
Flow Gauge
802310
802001
802051N
802051S
Rain Gauge
802049R
802051R
802053R
802303R
Build
Statistics
Options
Print
Print All
Zoom
Zoom Extents
Close
Rainfall (mm/h)
Discharge (l/s)
Velocity (m/s)
Depth (mm)
Time (h)
29/09/2025
05/10/2025
Measured
Simulated


Event Statistics
Rainfall
Total measured depth (mm) 0.13
Peak measured intensity (mm/h) 0.28
Mean measured intensity (mm/h) 0.0008
Discharge
Total measured volume (cu.m) 949946.67
Total simulated volume (cu.m) 014802.44
Ratio 1.07
Peak measured flow (l/s) 2184.19
Peak simulated flow (l/s) 2309.60
Ratio 1.06
Mean measured flow (l/s) 1577.72
Mean simulated flow (l/s) 1684.79
Ratio 1.07
Velocity
Peak measured velocity (m/s) 0.60
Peak simulated velocity (m/s) 0.65
Ratio 1.09
Mean measured velocity (m/s) 0.53
Mean simulated velocity (m/s) 0.59
Ratio 1.10
Depth
Peak measured depth (mm) 1421
Peak simulated depth (mm) 1291
Ratio 0.91
Mean measured depth (mm) 1209
Mean simulated depth (mm) 1084
Ratio 0.90
Close

802001 DW3





Event Statistics

Rainfall

Total measured depth (mm)	0.00	Peak measured intensity (mm/h)	0.00	Mean measured intensity (mm/h)	0.0000

Discharge

Total measured volume (cu.m)	137256.39	Peak measured flow (l/s)	2666.85	Mean measured flow (l/s)	1877.59
Total simulated volume (cu.m)	143061.24	Peak simulated flow (l/s)	2706.40	Mean simulated flow (l/s)	1897.73
Ratio	1.01	Ratio	1.01	Ratio	1.01

Velocity

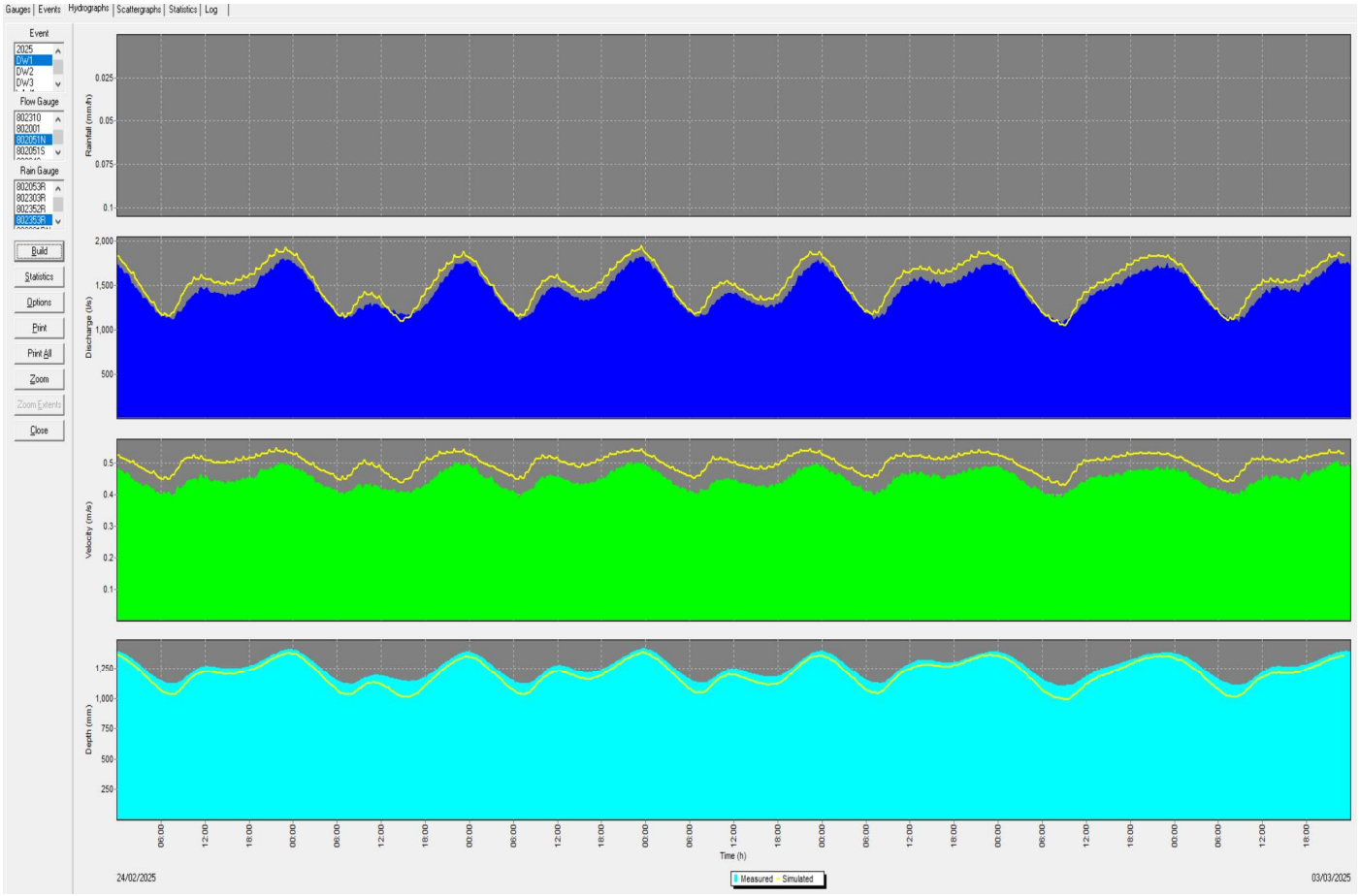
Peak measured velocity (m/s)	0.67	Mean measured velocity (m/s)	0.59
Peak simulated velocity (m/s)	0.68	Mean simulated velocity (m/s)	0.61
Ratio	1.00	Ratio	1.03

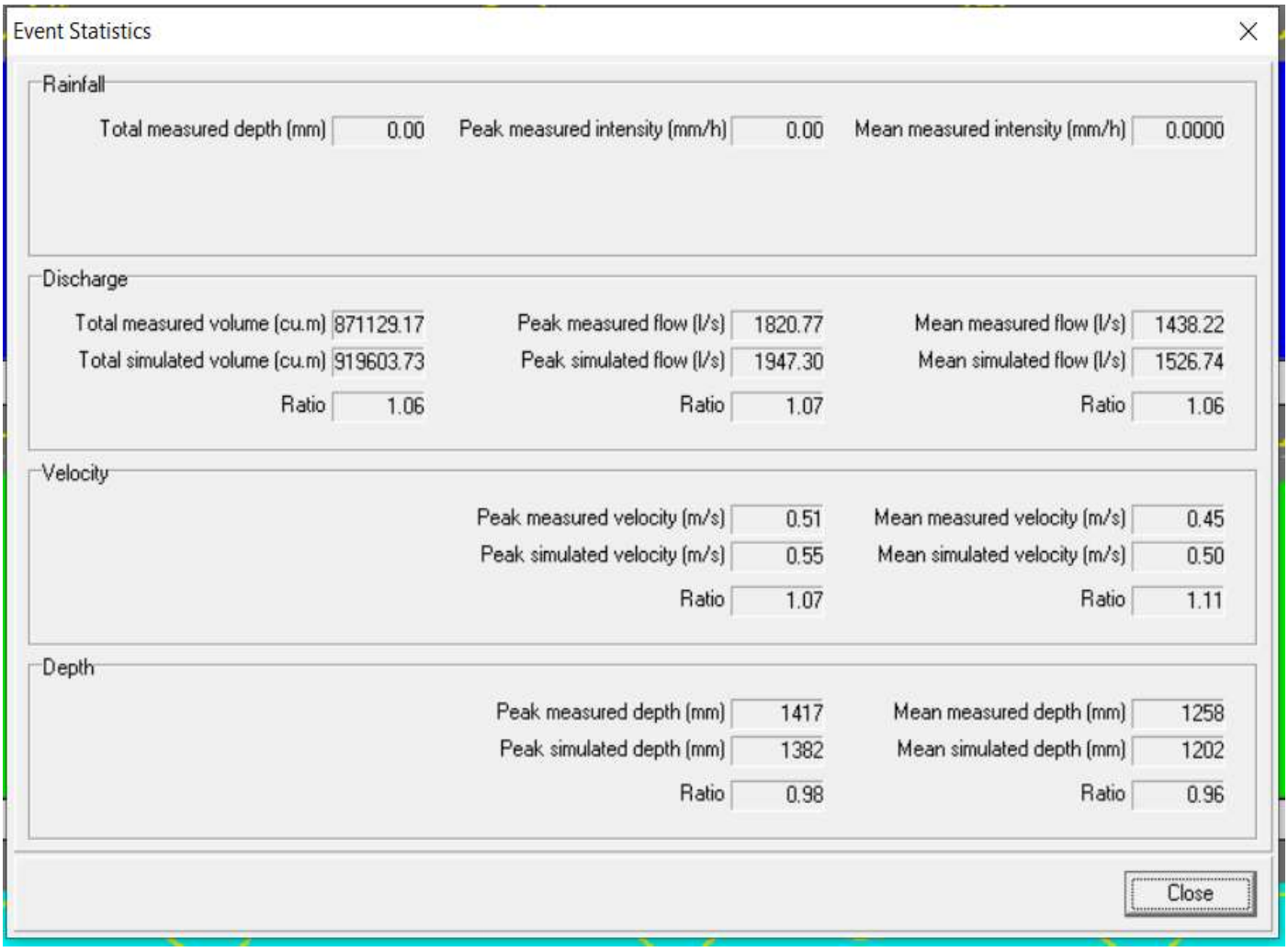
Depth

Peak measured depth (mm)	1518	Mean measured depth (mm)	1251
Peak simulated depth (mm)	1430	Mean simulated depth (mm)	1156
Ratio	0.94	Ratio	0.92

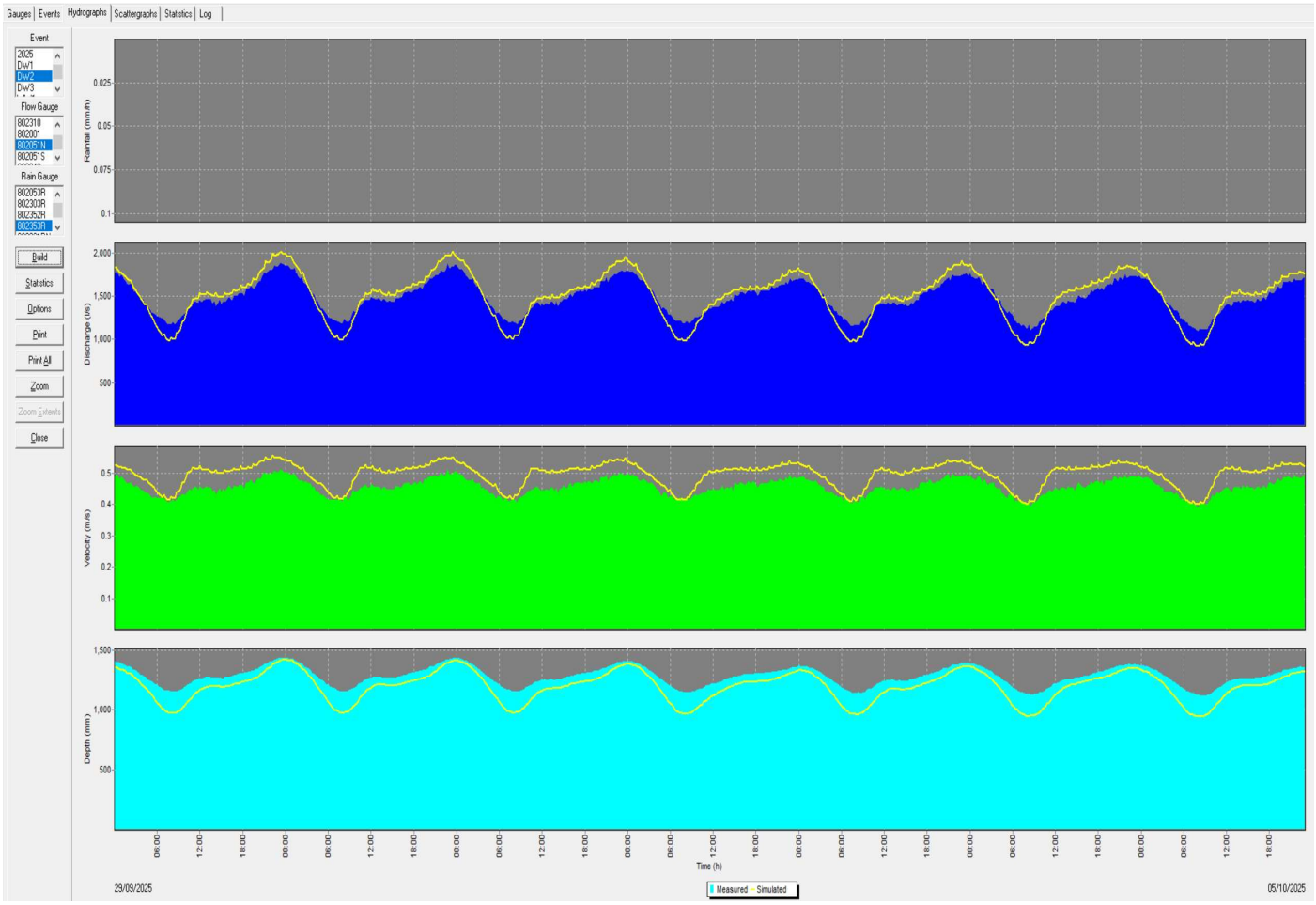
Close

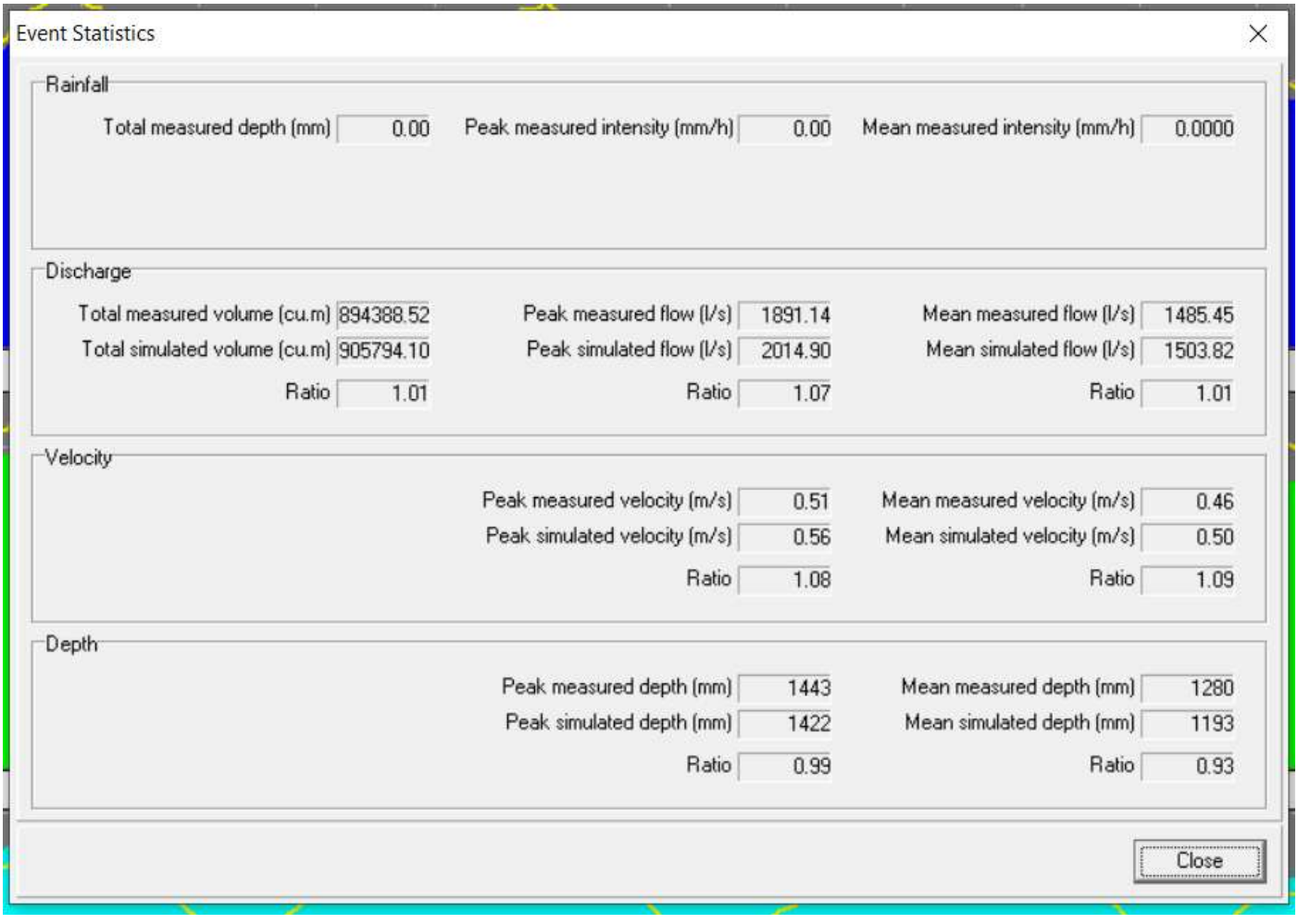
802051N DW1


Gauges | Events | Hydrographs | Scattergraphs | Statistics | Log
Event
2025
DW1
DW2
DW3
Flow Gauge
802310
802001
802051N
802051S
Rain Gauge
802053R
802303R
802352R
802353R
Build
Statistics
Options
Print
Print All
Zoom
Zoom Extents
Close
Rainfall (mm/h)
Discharge (l/s)
Velocity (m/s)
Depth (mm)
Time (h)
24/02/2025
Measured
Simulated
03/03/2025

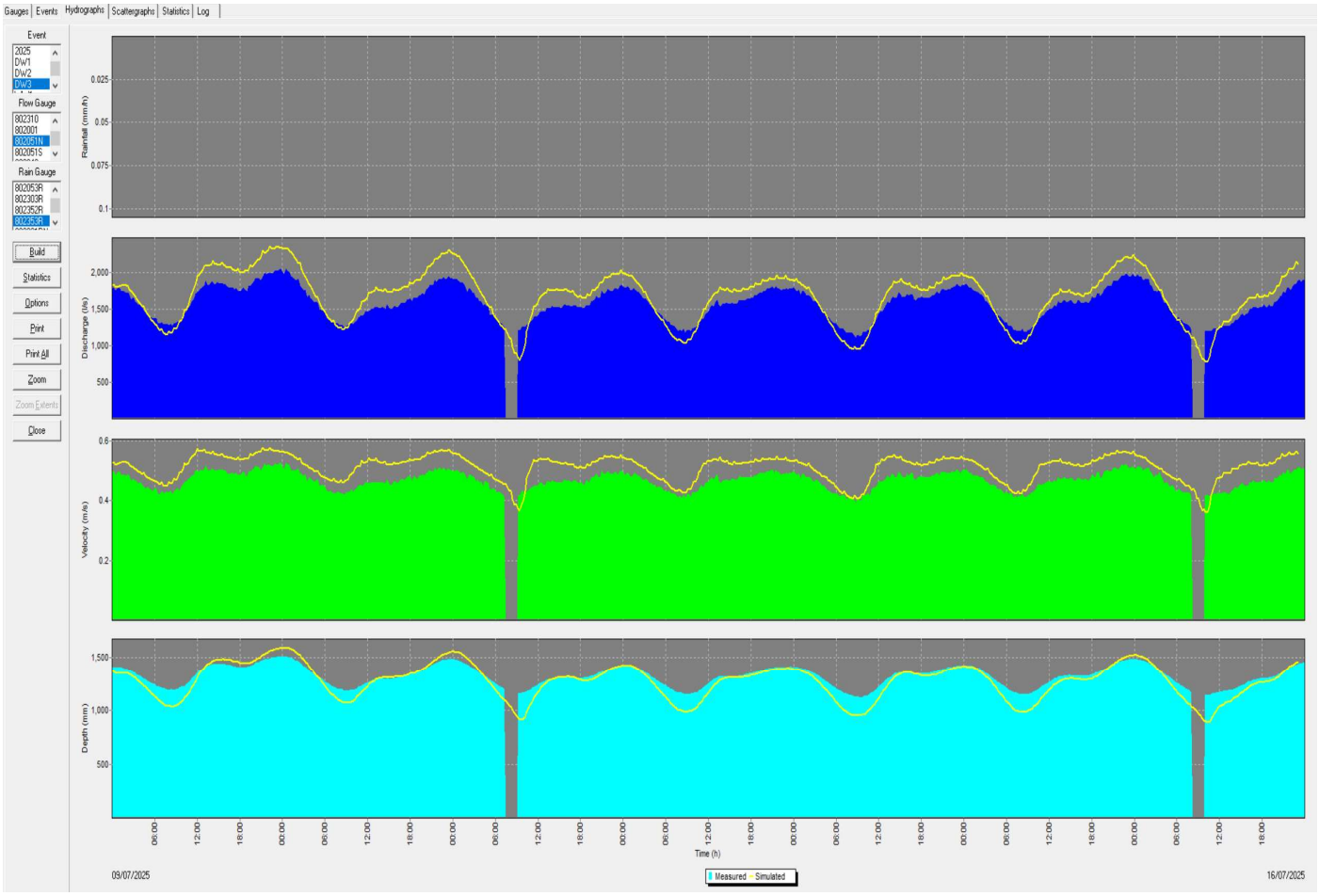

Event Statistics
Rainfall
Total measured depth (mm) 0.00
Peak measured intensity (mm/h) 0.00
Mean measured intensity (mm/h) 0.0000
Discharge
Total measured volume (cu.m) 871129.17
Peak measured flow (l/s) 1820.77
Mean measured flow (l/s) 1438.22
Total simulated volume (cu.m) 919603.73
Peak simulated flow (l/s) 1947.30
Mean simulated flow (l/s) 1526.74
Ratio 1.06
Ratio 1.07
Ratio 1.06
Velocity
Peak measured velocity (m/s) 0.51
Mean measured velocity (m/s) 0.45
Peak simulated velocity (m/s) 0.55
Mean simulated velocity (m/s) 0.50
Ratio 1.07
Ratio 1.11
Depth
Peak measured depth (mm) 1417
Mean measured depth (mm) 1258
Peak simulated depth (mm) 1382
Mean simulated depth (mm) 1202
Ratio 0.98
Ratio 0.96
Close

802051N DW2


Gauges
Events
Hydrographs
Scattergraphs
Statistics
Log
Event
2025
DW1
DW2
DW3
Flow Gauge
802310
802001
802051N
802051S
Rain Gauge
802053R
802303R
802352R
802353R
Build
Statistics
Options
Print
Print All
Zoom
Zoom Extents
Close
Rainfall (mm/h)
Discharge (l/s)
Velocity (m/s)
Depth (mm)
Time (h)
29/09/2025
Measured
Simulated
05/10/2025

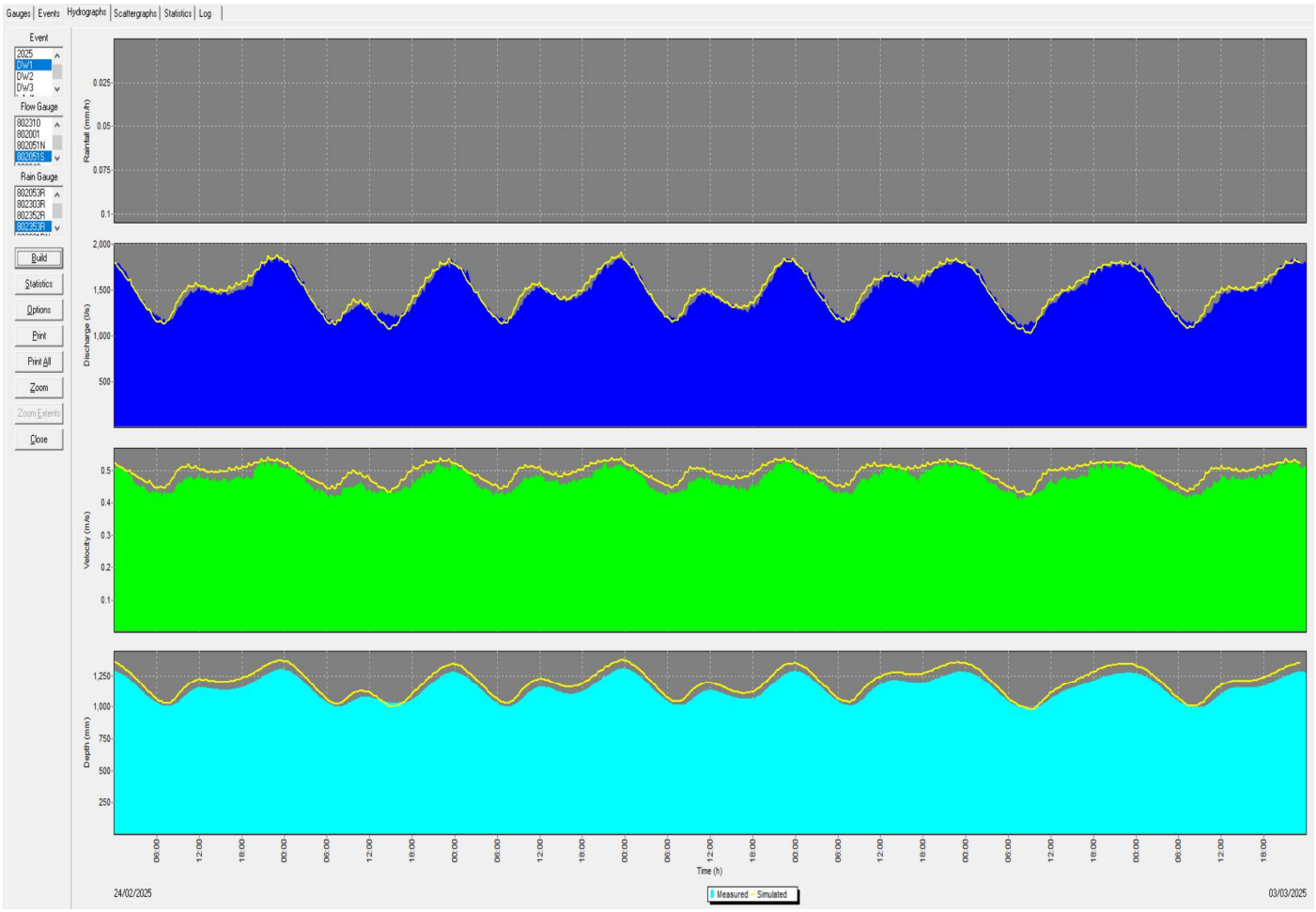

Event Statistics
Rainfall
Total measured depth (mm) 0.00
Peak measured intensity (mm/h) 0.00
Mean measured intensity (mm/h) 0.0000
Discharge
Total measured volume (cu.m) 894388.52
Peak measured flow (l/s) 1891.14
Mean measured flow (l/s) 1485.45
Total simulated volume (cu.m) 905794.10
Peak simulated flow (l/s) 2014.90
Mean simulated flow (l/s) 1503.82
Ratio 1.01
Ratio 1.07
Ratio 1.01
Velocity
Peak measured velocity (m/s) 0.51
Mean measured velocity (m/s) 0.46
Peak simulated velocity (m/s) 0.56
Mean simulated velocity (m/s) 0.50
Ratio 1.08
Ratio 1.09
Depth
Peak measured depth (mm) 1443
Mean measured depth (mm) 1280
Peak simulated depth (mm) 1422
Mean simulated depth (mm) 1193
Ratio 0.99
Ratio 0.93
Close

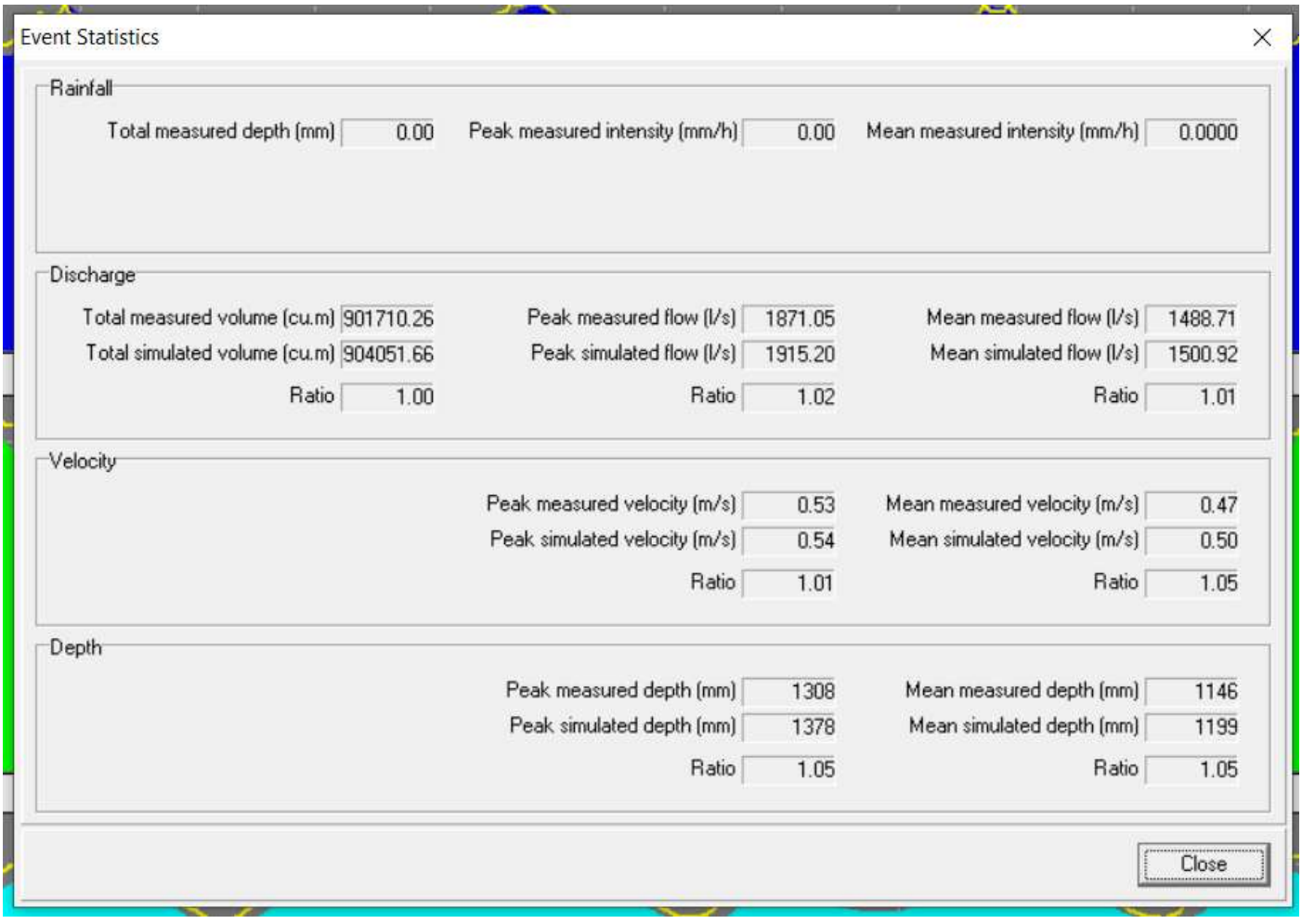
802051N DW3


Gauges | Events | Hydrographs | Scattergraphs | Statistics | Log
Event
2025
DW1
DW2
DW3
Flow Gauge
802310
802001
802051N
802051S
Rain Gauge
802053R
802303R
802352R
802353R
Build
Statistics
Options
Print
Print All
Zoom
Zoom Events
Close
Rainfall (mm/h)
Discharge (l/s)
Velocity (m/s)
Depth (mm)
Time (h)
09/07/2025
16/07/2025
Measured
Simulated


Event Statistics
Rainfall
Total measured depth (mm) 0.00
Peak measured intensity (mm/h) 0.00
Mean measured intensity (mm/h) 0.0000
Discharge
Total measured volume (cu.m) 938681.52
Peak measured flow (l/s) 2048.68
Mean measured flow (l/s) 1549.75
Total simulated volume (cu.m) 008141.75
Peak simulated flow (l/s) 2352.20
Mean simulated flow (l/s) 1673.74
Ratio 1.07
Ratio 1.15
Ratio 1.08
Velocity
Peak measured velocity (m/s) 0.53
Mean measured velocity (m/s) 0.46
Peak simulated velocity (m/s) 0.58
Mean simulated velocity (m/s) 0.51
Ratio 1.09
Ratio 1.12
Depth
Peak measured depth (mm) 1510
Mean measured depth (mm) 1295
Peak simulated depth (mm) 1592
Mean simulated depth (mm) 1275
Ratio 1.05
Ratio 0.98
Close

802051S DW1





Event Statistics

Rainfall

Total measured depth (mm)	0.00	Peak measured intensity (mm/h)	0.00	Mean measured intensity (mm/h)	0.0000

Discharge

Total measured volume (cu.m)	901710.26	Peak measured flow (l/s)	1871.05	Mean measured flow (l/s)	1488.71
Total simulated volume (cu.m)	904051.66	Peak simulated flow (l/s)	1915.20	Mean simulated flow (l/s)	1500.92
Ratio	1.00	Ratio	1.02	Ratio	1.01

Velocity

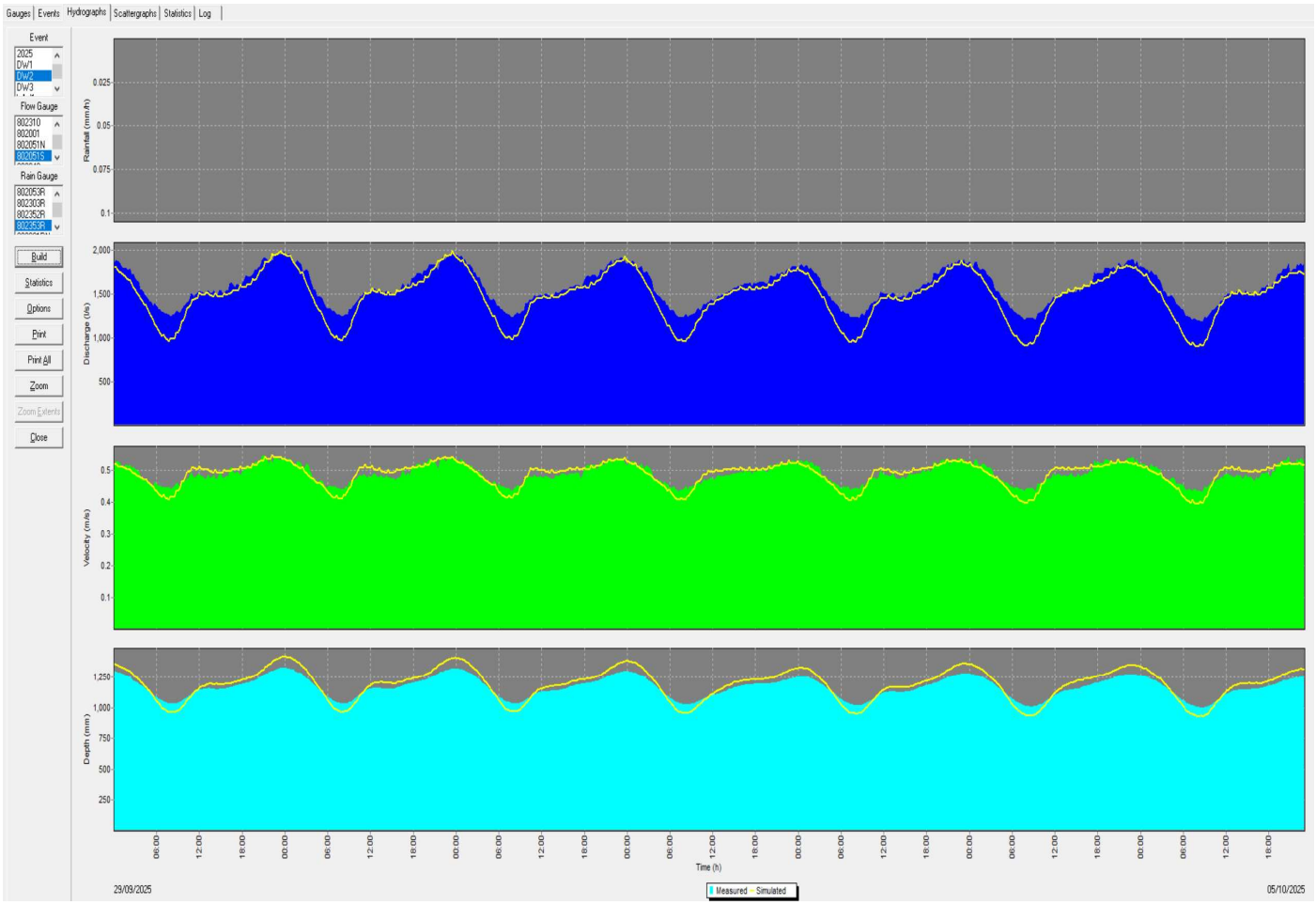
Peak measured velocity (m/s)	0.53	Mean measured velocity (m/s)	0.47
Peak simulated velocity (m/s)	0.54	Mean simulated velocity (m/s)	0.50
Ratio	1.01	Ratio	1.05

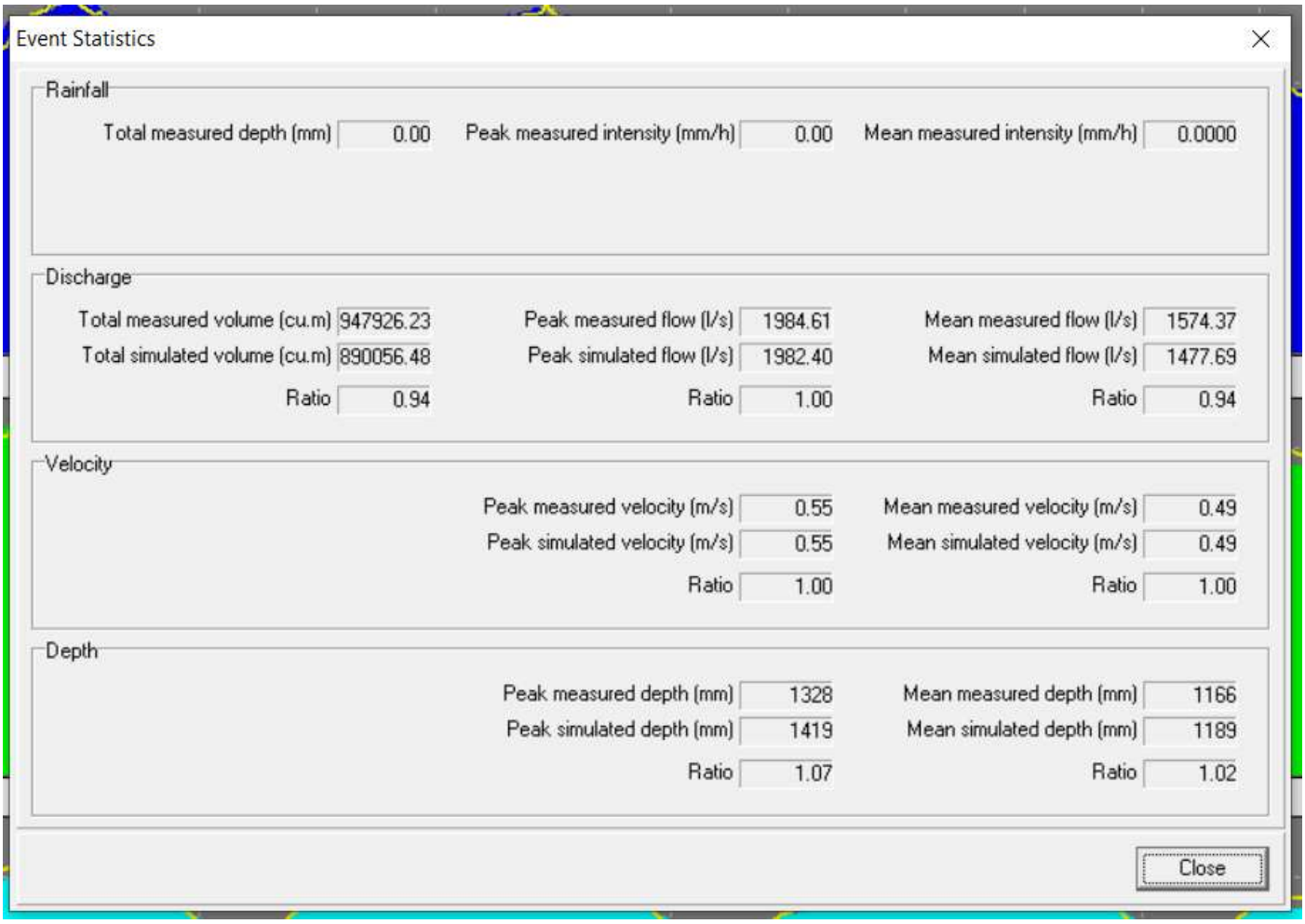
Depth

Peak measured depth (mm)	1308	Mean measured depth (mm)	1146
Peak simulated depth (mm)	1378	Mean simulated depth (mm)	1199
Ratio	1.05	Ratio	1.05

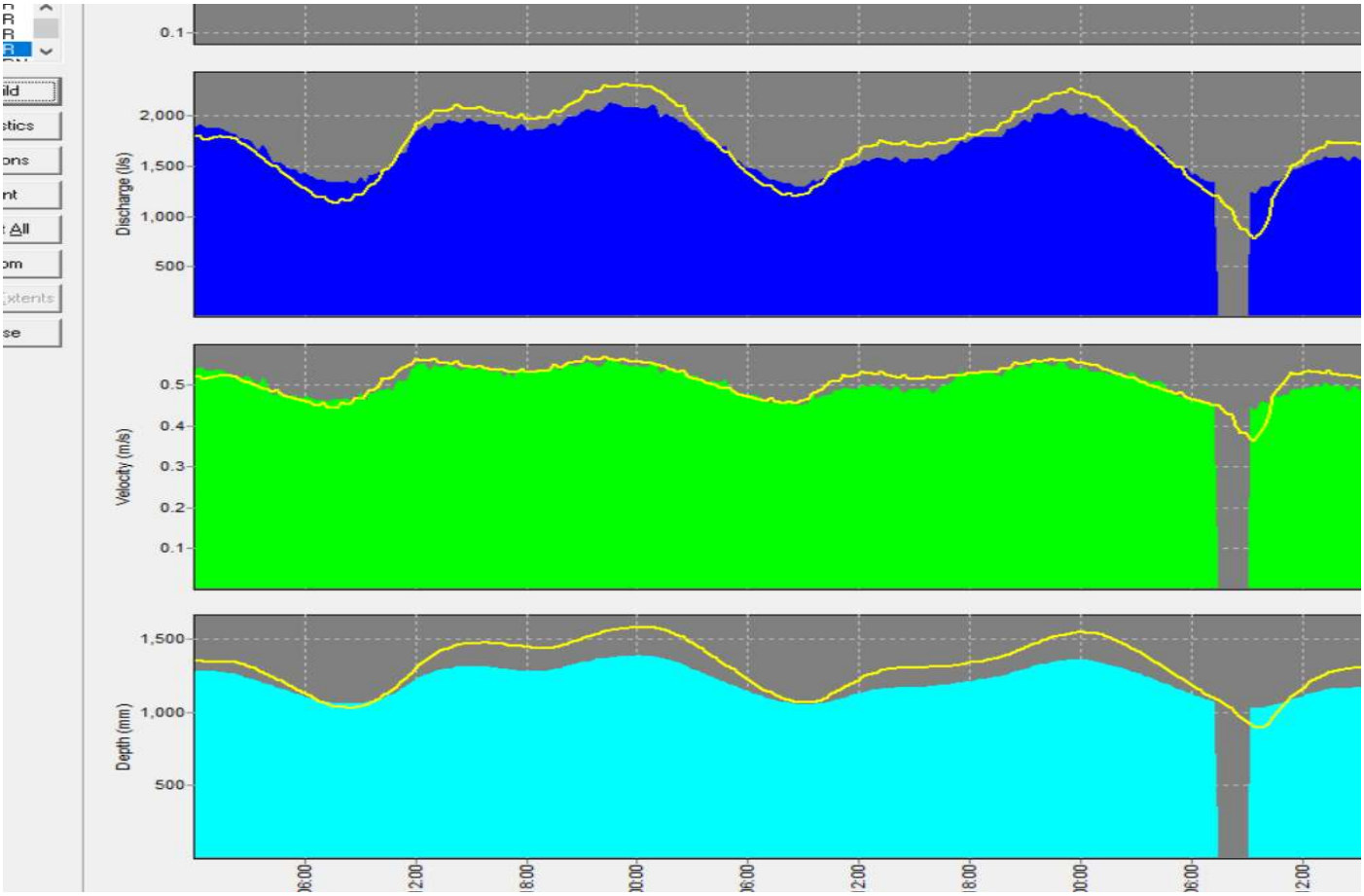
Close

802051S DW2


Gauges
Events
Hydrographs
Scattergraphs
Statistics
Log
Event
2025
DW1
DW2
DW3
Flow Gauge
802310
802001
802051N
802051S
Rain Gauge
802053R
802303R
802352R
802353R
Build
Statistics
Options
Print
Print All
Zoom
Zoom Extents
Close
Rainfall (mm/h)
Discharge (l/s)
Velocity (m/s)
Depth (mm)
Time (h)
29/09/2025
Measured
Simulated
05/10/2025


Event Statistics
Rainfall
Total measured depth (mm) 0.00
Peak measured intensity (mm/h) 0.00
Mean measured intensity (mm/h) 0.0000
Discharge
Total measured volume (cu.m) 947926.23
Peak measured flow (l/s) 1984.61
Mean measured flow (l/s) 1574.37
Total simulated volume (cu.m) 890056.48
Peak simulated flow (l/s) 1982.40
Mean simulated flow (l/s) 1477.69
Ratio 0.94
Ratio 1.00
Ratio 0.94
Velocity
Peak measured velocity (m/s) 0.55
Mean measured velocity (m/s) 0.49
Peak simulated velocity (m/s) 0.55
Mean simulated velocity (m/s) 0.49
Ratio 1.00
Ratio 1.00
Depth
Peak measured depth (mm) 1328
Mean measured depth (mm) 1166
Peak simulated depth (mm) 1419
Mean simulated depth (mm) 1189
Ratio 1.07
Ratio 1.02
Close

802051S DW3



Event Statistics

Rainfall

Total measured depth (mm)	0.00	Peak measured intensity (mm/h)	0.00	Mean measured intensity (mm/h)	0.0000

Discharge

Total measured volume (cu.m)	862175.43	Peak measured flow (l/s)	2144.54	Mean measured flow (l/s)	1618.20
Total simulated volume (cu.m)	867185.20	Peak simulated flow (l/s)	2321.10	Mean simulated flow (l/s)	1637.71
Ratio	1.01	Ratio	1.08	Ratio	1.01

Velocity

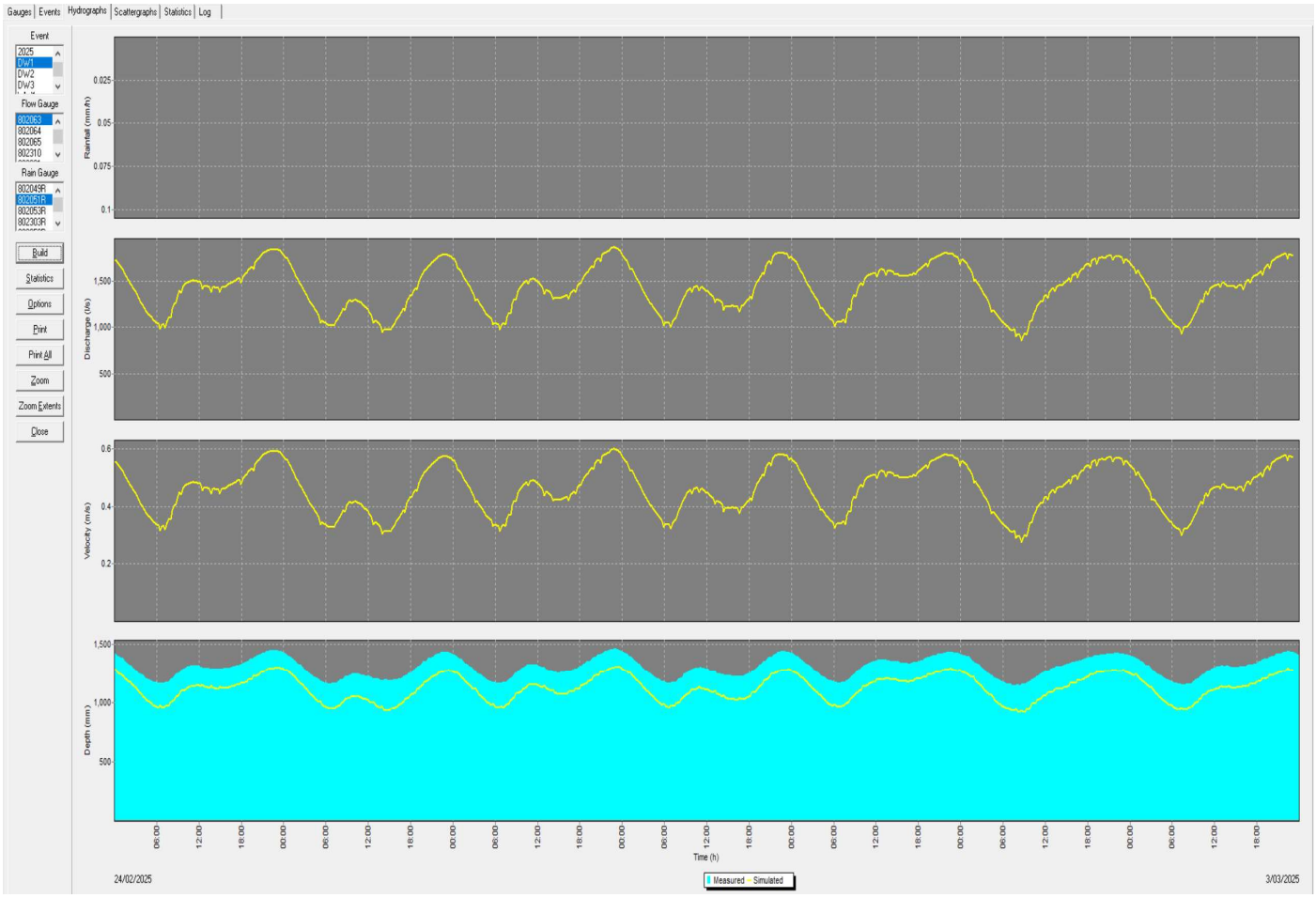
Peak measured velocity (m/s)	0.57	Mean measured velocity (m/s)	0.49
Peak simulated velocity (m/s)	0.57	Mean simulated velocity (m/s)	0.50
Ratio	1.00	Ratio	1.03

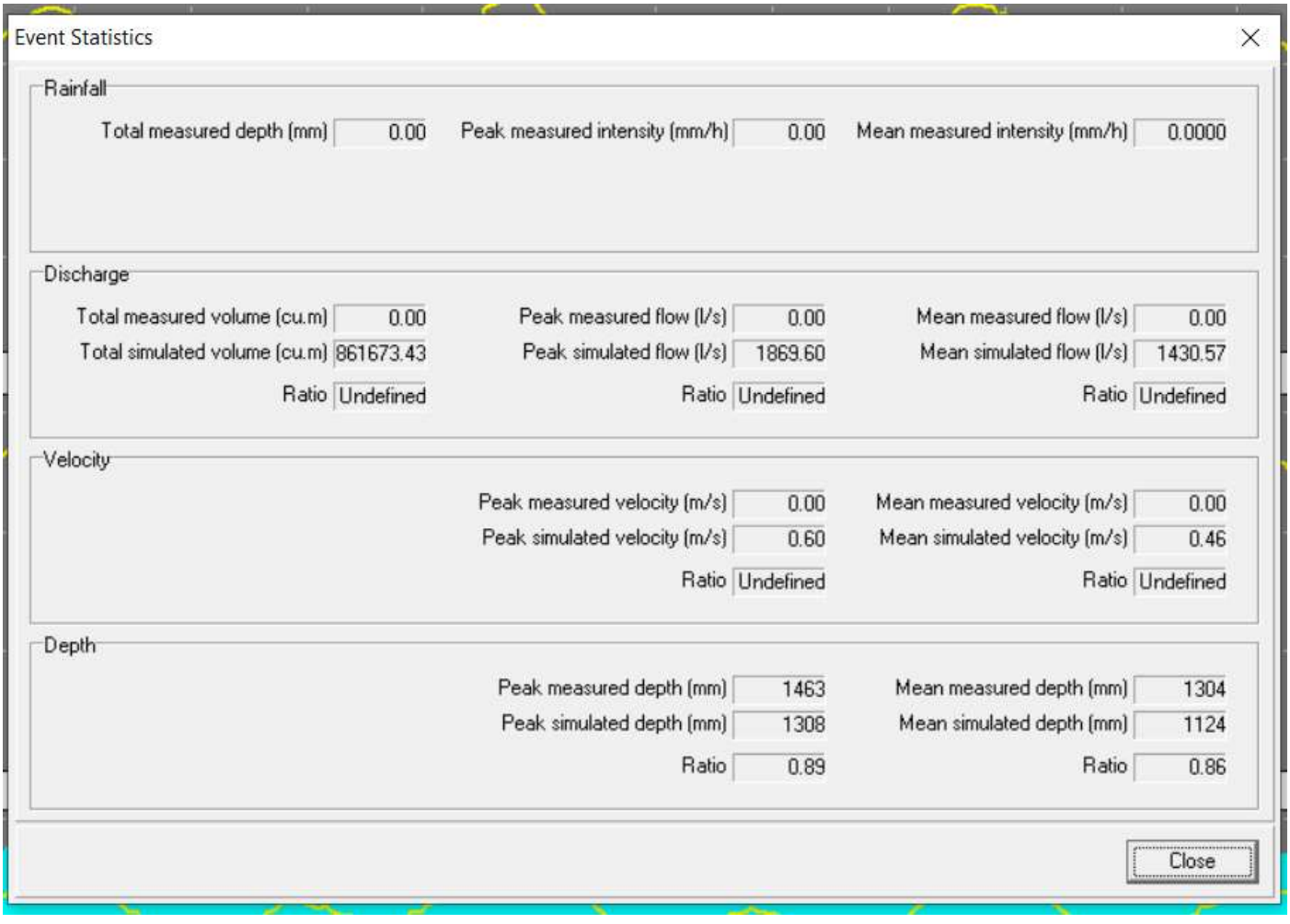
Depth

Peak measured depth (mm)	1390	Mean measured depth (mm)	1169
Peak simulated depth (mm)	1589	Mean simulated depth (mm)	1268
Ratio	1.14	Ratio	1.08

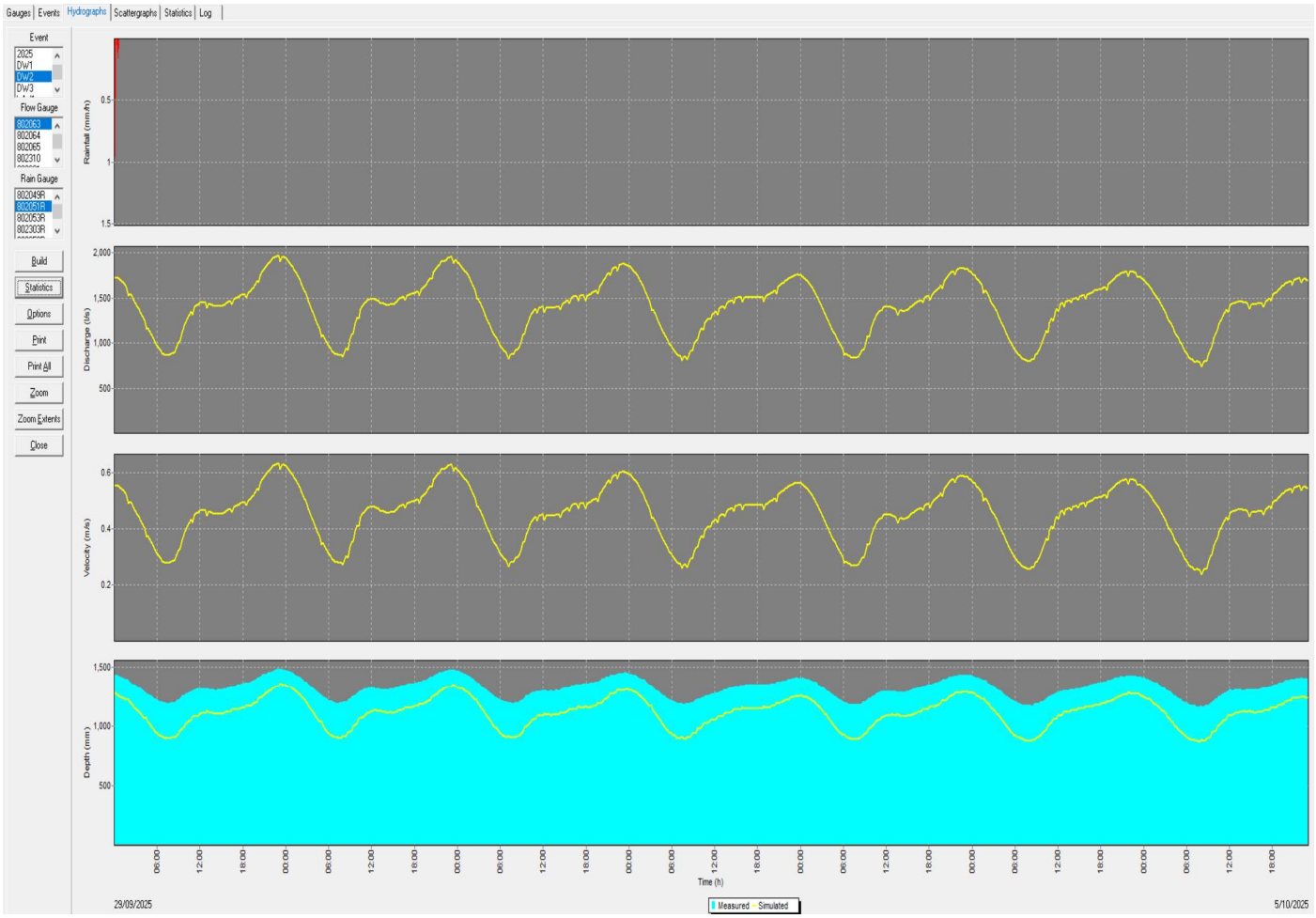
Close

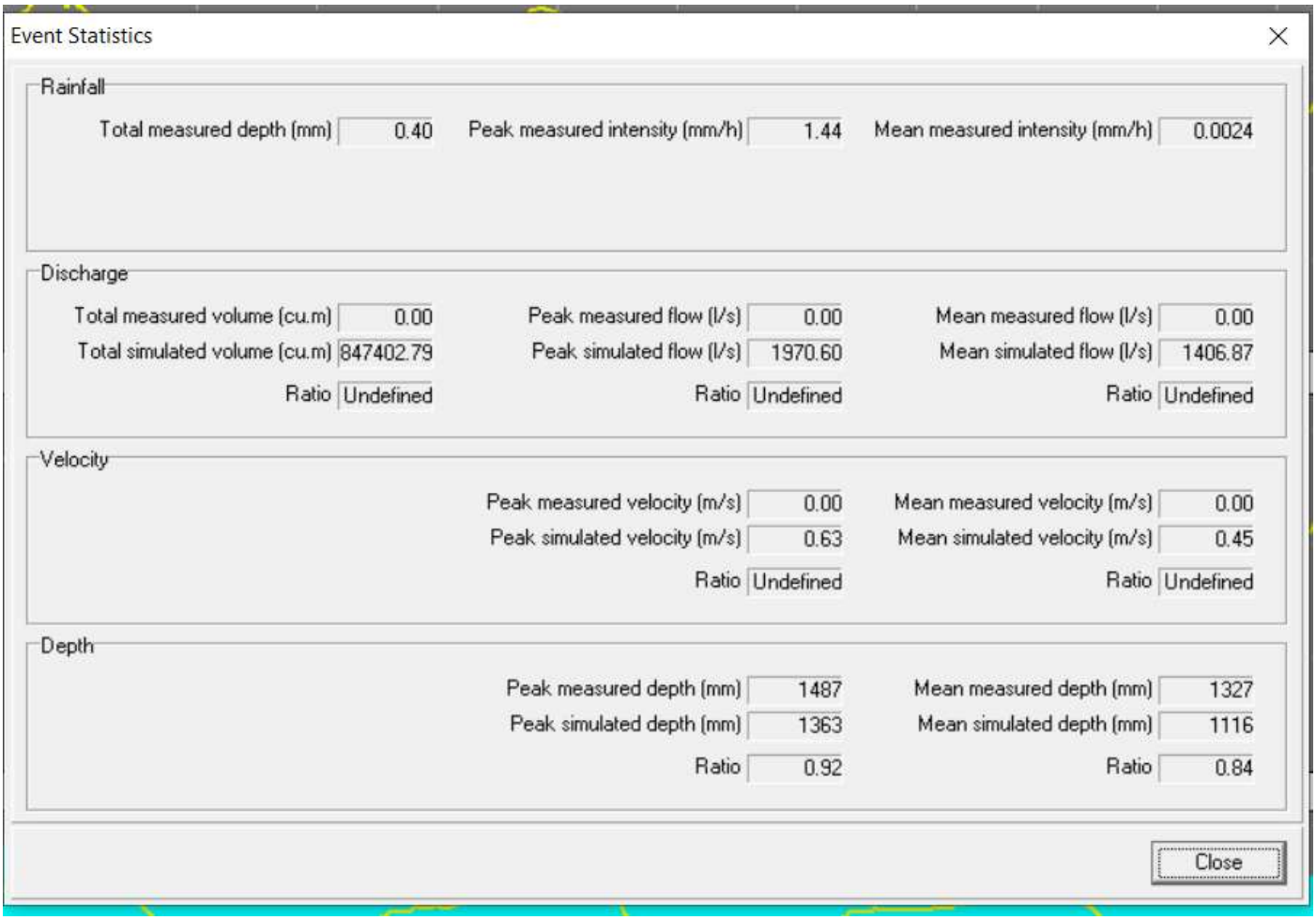
802063 DW1


Gauges | Events | Hydrographs | Scattergraphs | Statistics | Log
Event
2025
DW1
DW2
DW3
Flow Gauge
802063
802064
802065
802310
Rain Gauge
802049R
802051R
802053R
802303R
Build
Statistics
Options
Print
Print All
Zoom
Zoom Extents
Close
Rainfall (mm/h)
Discharge (l/s)
Velocity (m/s)
Depth (mm)
Time (h)
24/02/2025
Measured
Simulated
3/03/2025

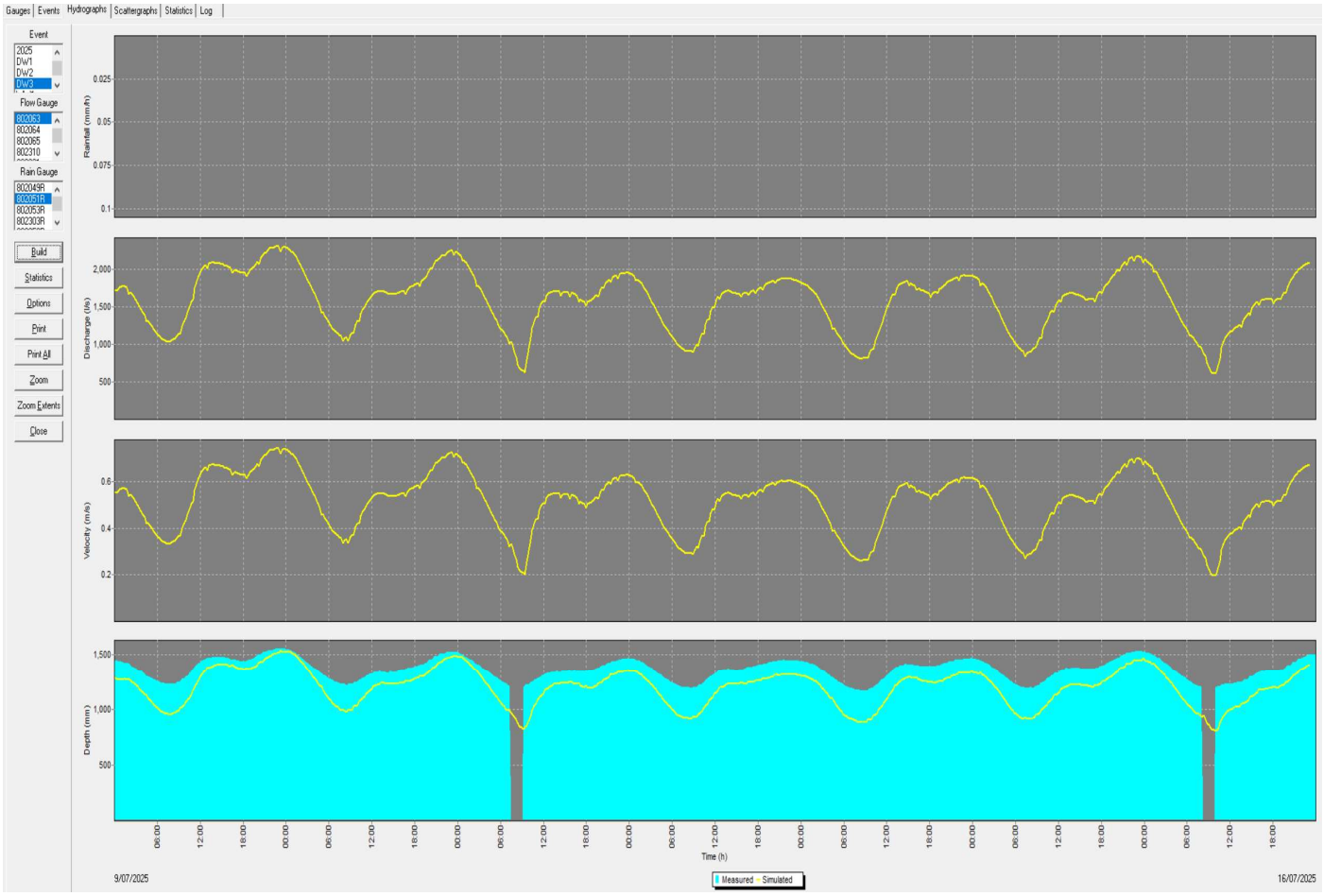

Event Statistics
Rainfall
Total measured depth (mm) 0.00
Peak measured intensity (mm/h) 0.00
Mean measured intensity (mm/h) 0.0000
Discharge
Total measured volume (cu.m) 0.00
Peak measured flow (l/s) 0.00
Mean measured flow (l/s) 0.00
Total simulated volume (cu.m) 861673.43
Peak simulated flow (l/s) 1869.60
Mean simulated flow (l/s) 1430.57
Ratio Undefined
Ratio Undefined
Ratio Undefined
Velocity
Peak measured velocity (m/s) 0.00
Mean measured velocity (m/s) 0.00
Peak simulated velocity (m/s) 0.60
Mean simulated velocity (m/s) 0.46
Ratio Undefined
Ratio Undefined
Depth
Peak measured depth (mm) 1463
Mean measured depth (mm) 1304
Peak simulated depth (mm) 1308
Mean simulated depth (mm) 1124
Ratio 0.89
Ratio 0.86
Close

802063 DW2


Gauges | Events | Hydrographs | Scattergraphs | Statistics | Log
Event
2025
DW1
DW2
DW3
Flow Gauge
802063
802064
802065
802310
Rain Gauge
802049R
802051R
802053R
802303R
Build
Statistics
Options
Print
Print All
Zoom
Zoom Extents
Close
Rainfall (mm/h)
Discharge (l/s)
Velocity (m/s)
Depth (mm)
Time (h)
29/09/2025
Measured
Simulated
5/10/2025

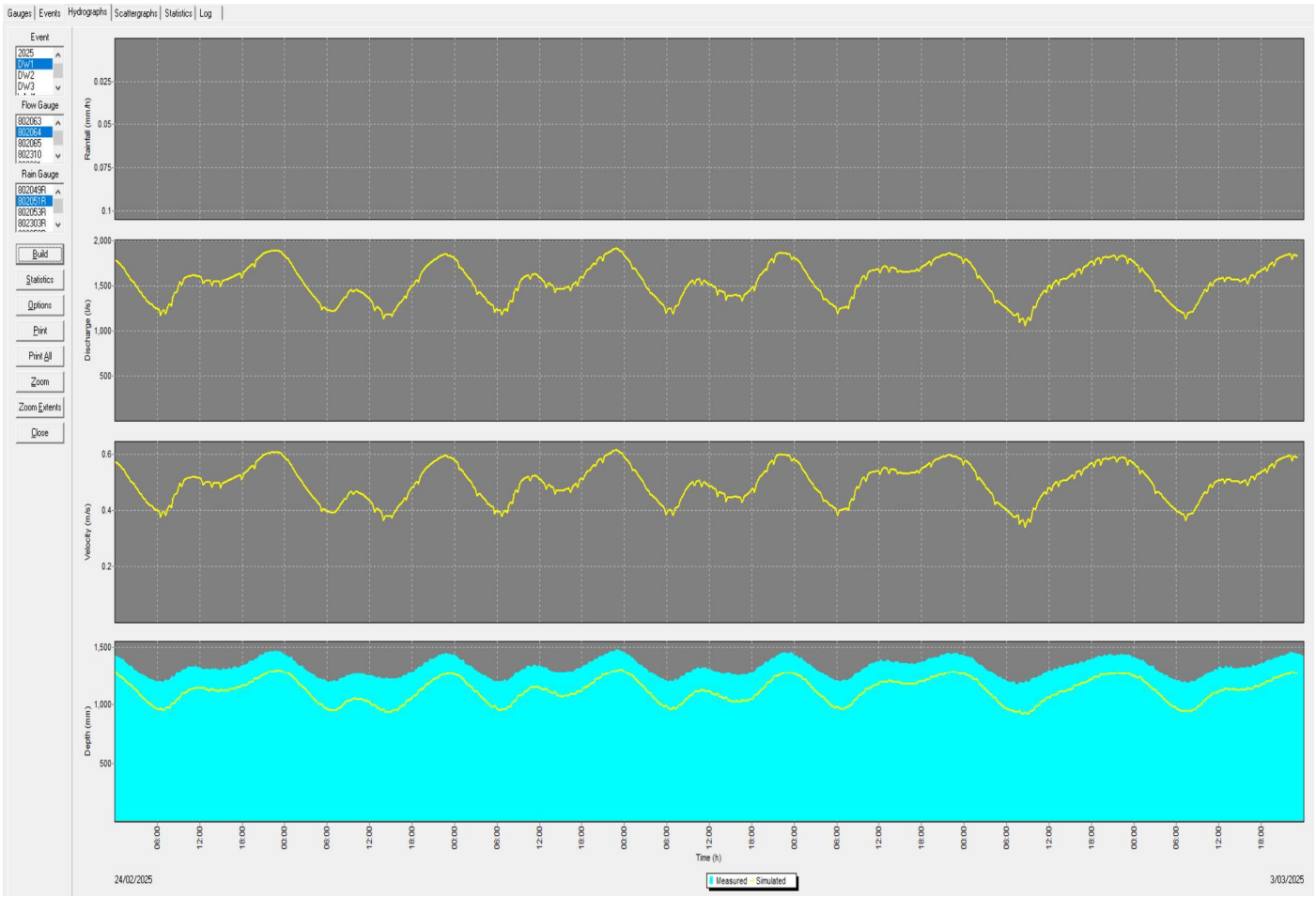

Event Statistics
Rainfall
Total measured depth (mm) 0.40
Peak measured intensity (mm/h) 1.44
Mean measured intensity (mm/h) 0.0024
Discharge
Total measured volume (cu.m) 0.00
Peak measured flow (l/s) 0.00
Mean measured flow (l/s) 0.00
Total simulated volume (cu.m) 847402.79
Peak simulated flow (l/s) 1970.60
Mean simulated flow (l/s) 1406.87
Ratio Undefined
Ratio Undefined
Ratio Undefined
Velocity
Peak measured velocity (m/s) 0.00
Mean measured velocity (m/s) 0.00
Peak simulated velocity (m/s) 0.63
Mean simulated velocity (m/s) 0.45
Ratio Undefined
Ratio Undefined
Depth
Peak measured depth (mm) 1487
Mean measured depth (mm) 1327
Peak simulated depth (mm) 1363
Mean simulated depth (mm) 1116
Ratio 0.92
Ratio 0.84
Close

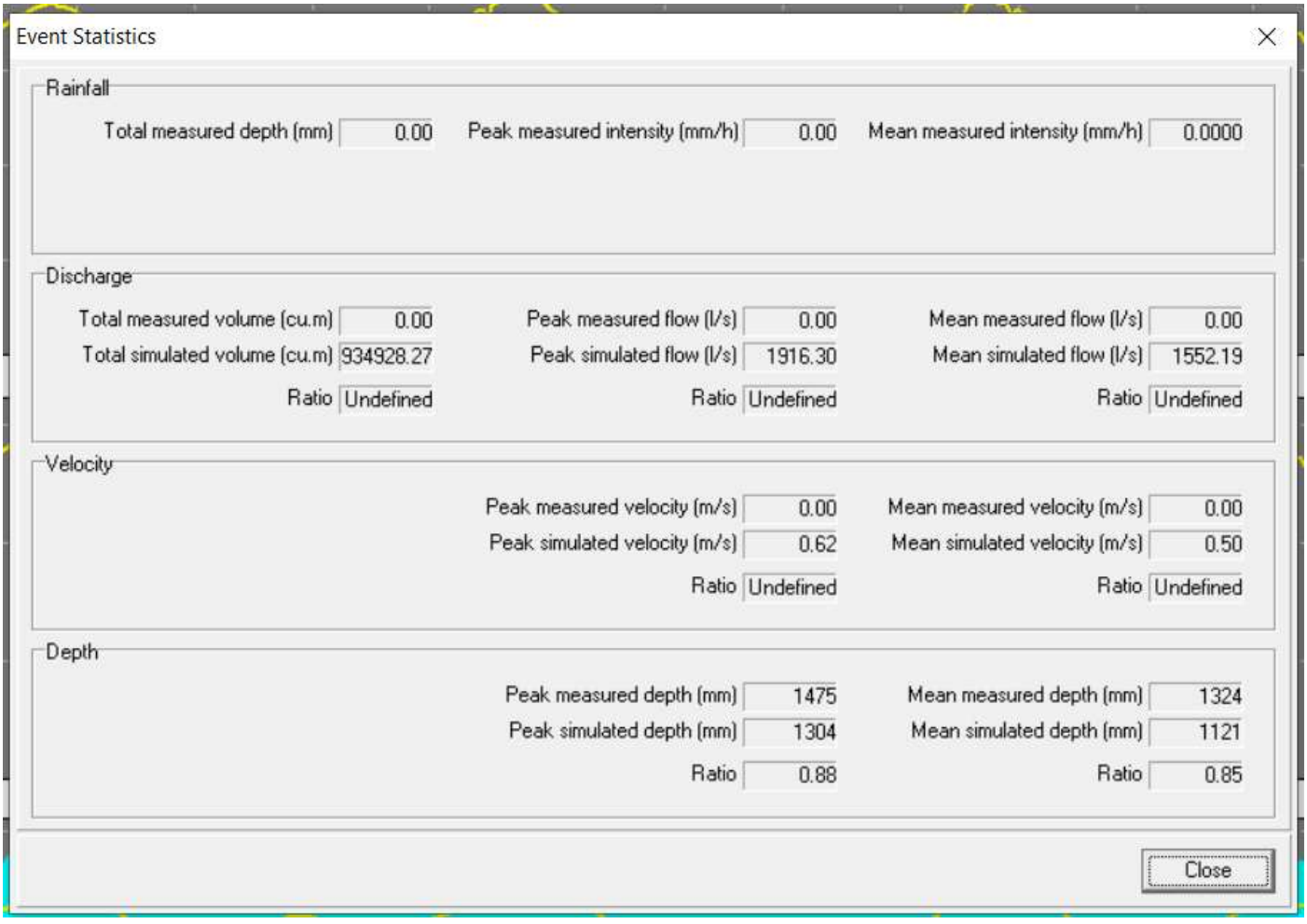
802603 DW3


Gauges | Events | Hydrographs | Scattergraphs | Statistics | Log
Event
2025
DW1
DW2
DW3
Flow Gauge
802063
802064
802065
802310
Rain Gauge
802049R
802051R
802052R
802303R
Build
Statistics
Options
Print
Print All
Zoom
Zoom Extents
Close
Rainfall (mm/h)
Discharge (l/s)
Velocity (m/s)
Depth (mm)
Time (h)
9/07/2025
Measured
Simulated
16/07/2025

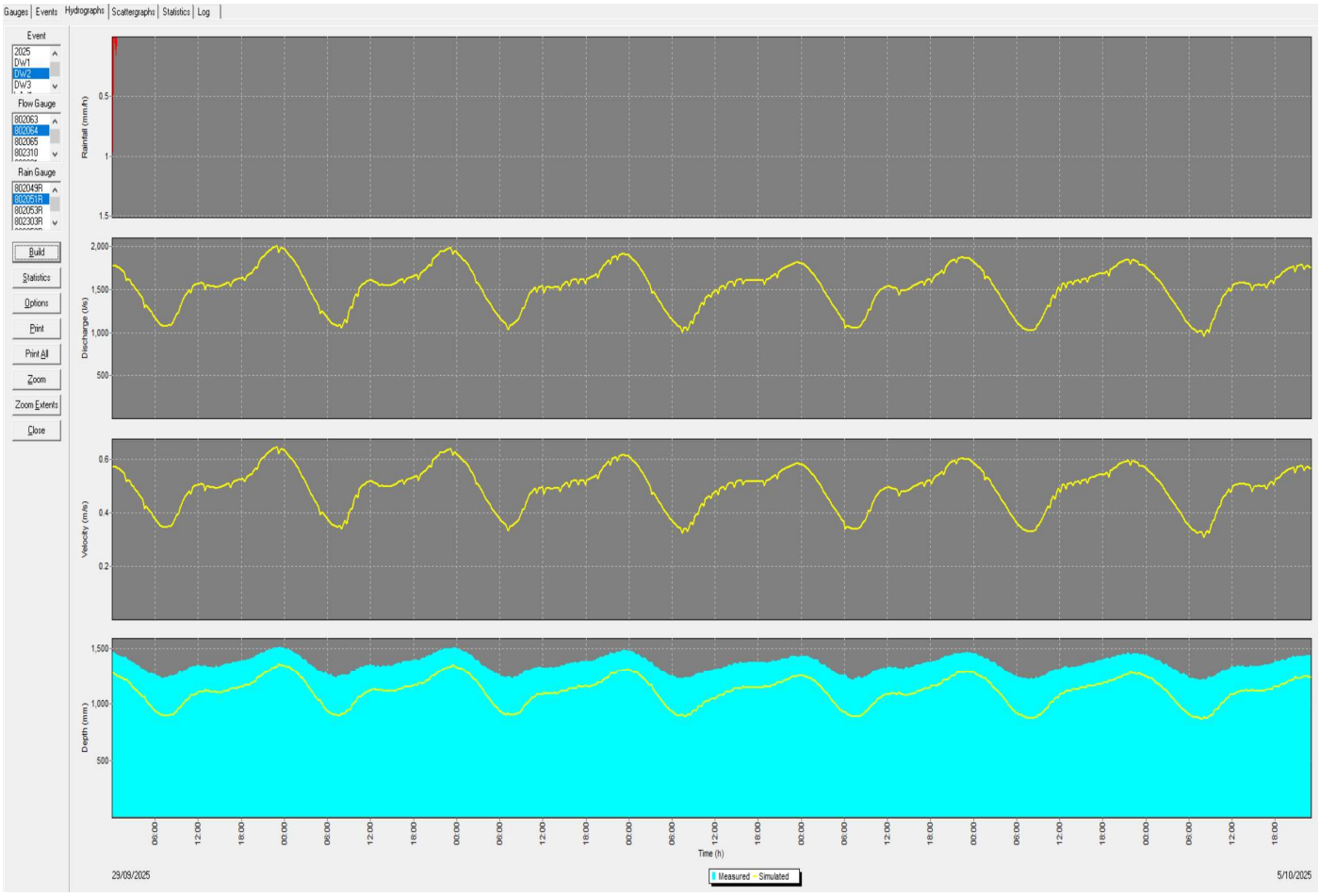

Event Statistics
Rainfall
Total measured depth (mm) 0.00
Peak measured intensity (mm/h) 0.00
Mean measured intensity (mm/h) 0.0000
Discharge
Total measured volume (cu.m) 0.00
Peak measured flow (l/s) 0.00
Mean measured flow (l/s) 0.00
Total simulated volume (cu.m) 958706.28
Peak simulated flow (l/s) 2308.80
Mean simulated flow (l/s) 1591.66
Ratio Undefined
Ratio Undefined
Ratio Undefined
Velocity
Peak measured velocity (m/s) 0.00
Mean measured velocity (m/s) 0.00
Peak simulated velocity (m/s) 0.74
Mean simulated velocity (m/s) 0.51
Ratio Undefined
Ratio Undefined
Depth
Peak measured depth (mm) 1550
Mean measured depth (mm) 1335
Peak simulated depth (mm) 1532
Mean simulated depth (mm) 1199
Ratio 0.99
Ratio 0.90
Close

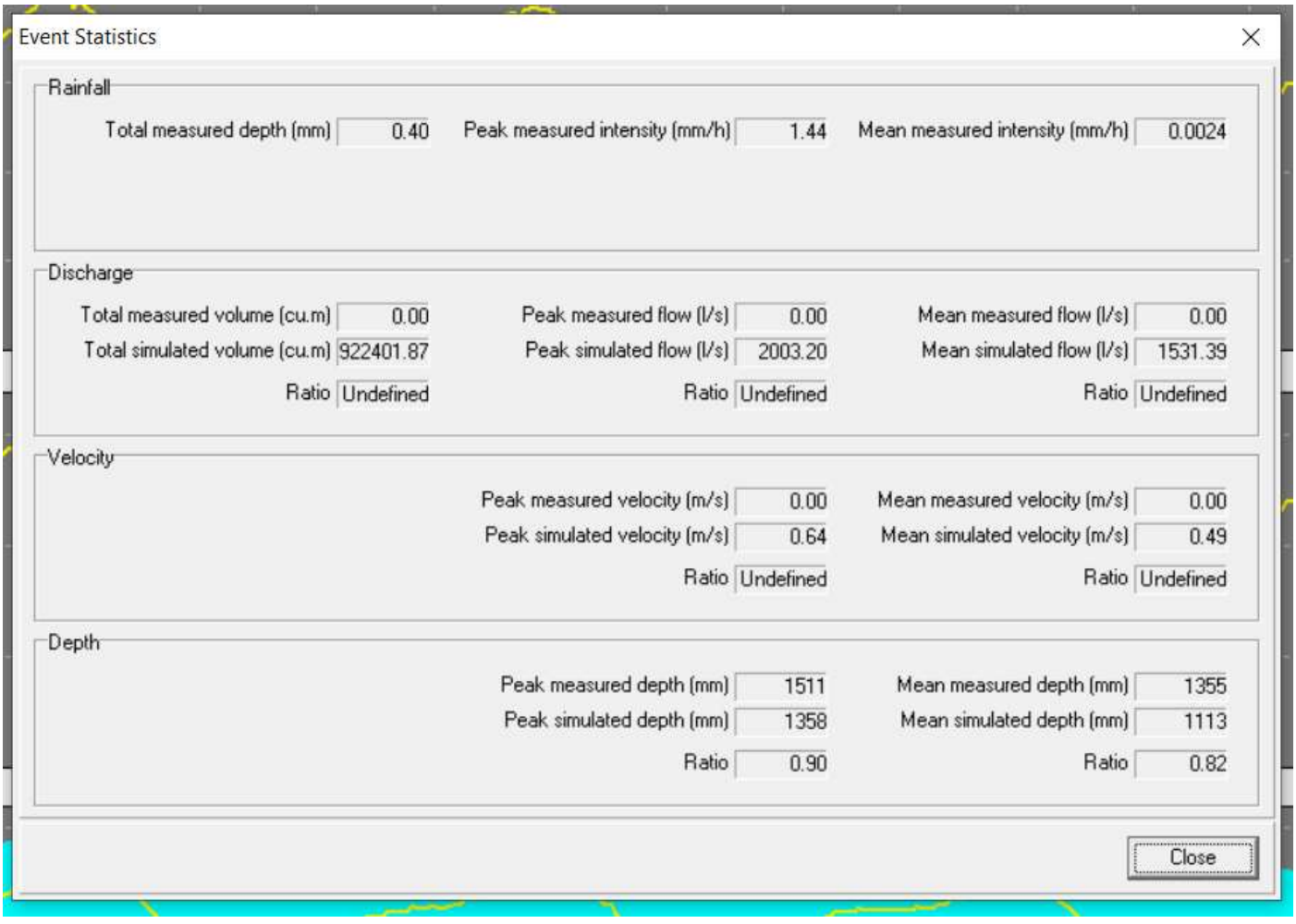
802064 DW1


Gauges | Events | Hydrographs | Scattergraphs | Statistics | Log
Event
2025
DW1
DW2
DW3
Flow Gauge
802063
802064
802065
802310
Rain Gauge
802049R
802051R
802053R
802303R
Build
Statistics
Options
Print
Print All
Zoom
Zoom Extents
Close
Rainfall (mm/h)
Discharge (l/s)
Velocity (m/s)
Depth (mm)
Time (h)
24/02/2025
Measured
Simulated
3/03/2025

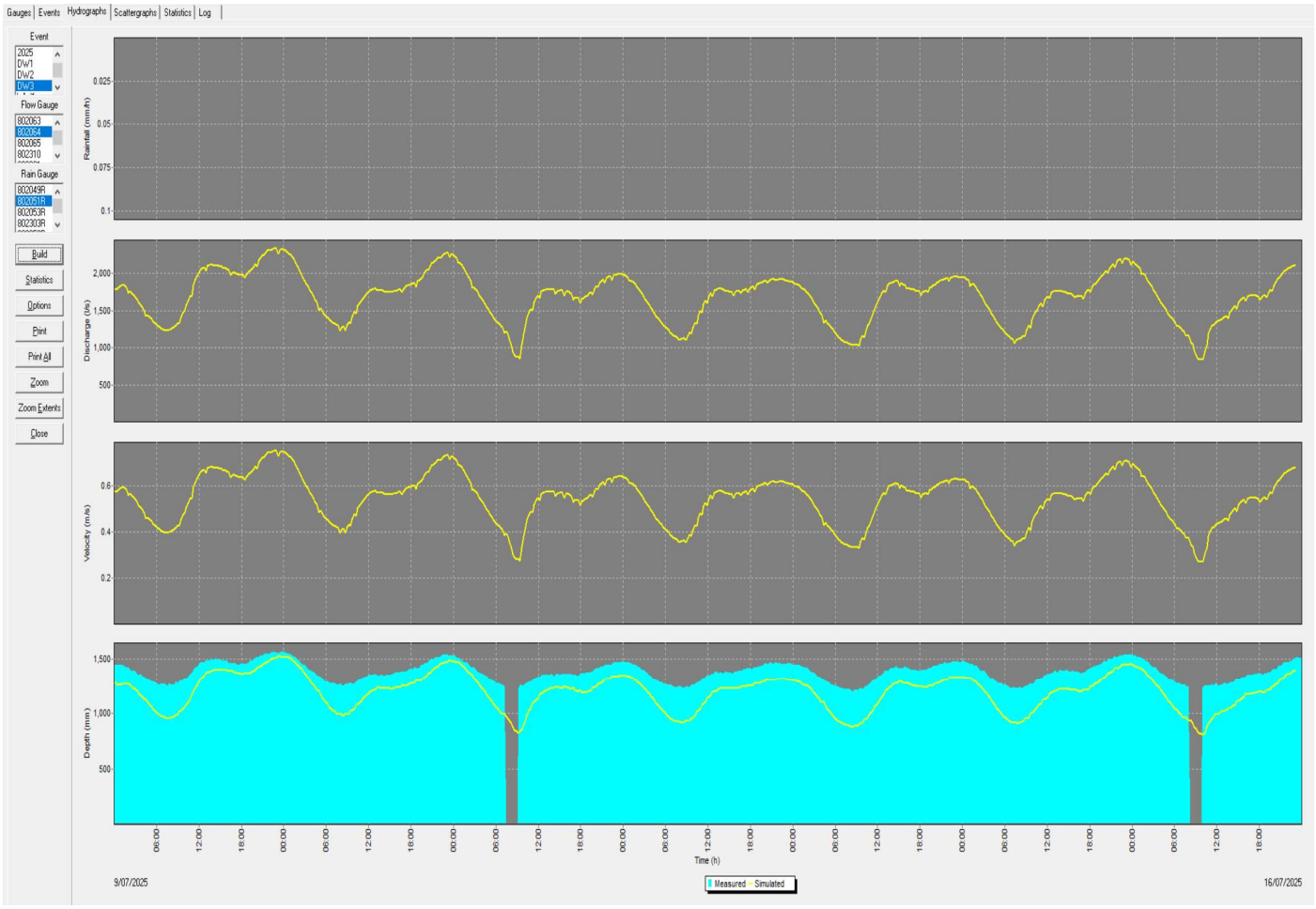

Event Statistics
Rainfall
Total measured depth (mm) 0.00
Peak measured intensity (mm/h) 0.00
Mean measured intensity (mm/h) 0.0000
Discharge
Total measured volume (cu.m) 0.00
Peak measured flow (l/s) 0.00
Mean measured flow (l/s) 0.00
Total simulated volume (cu.m) 934928.27
Peak simulated flow (l/s) 1916.30
Mean simulated flow (l/s) 1552.19
Ratio Undefined
Ratio Undefined
Ratio Undefined
Velocity
Peak measured velocity (m/s) 0.00
Mean measured velocity (m/s) 0.00
Peak simulated velocity (m/s) 0.62
Mean simulated velocity (m/s) 0.50
Ratio Undefined
Ratio Undefined
Depth
Peak measured depth (mm) 1475
Mean measured depth (mm) 1324
Peak simulated depth (mm) 1304
Mean simulated depth (mm) 1121
Ratio 0.88
Ratio 0.85
Close

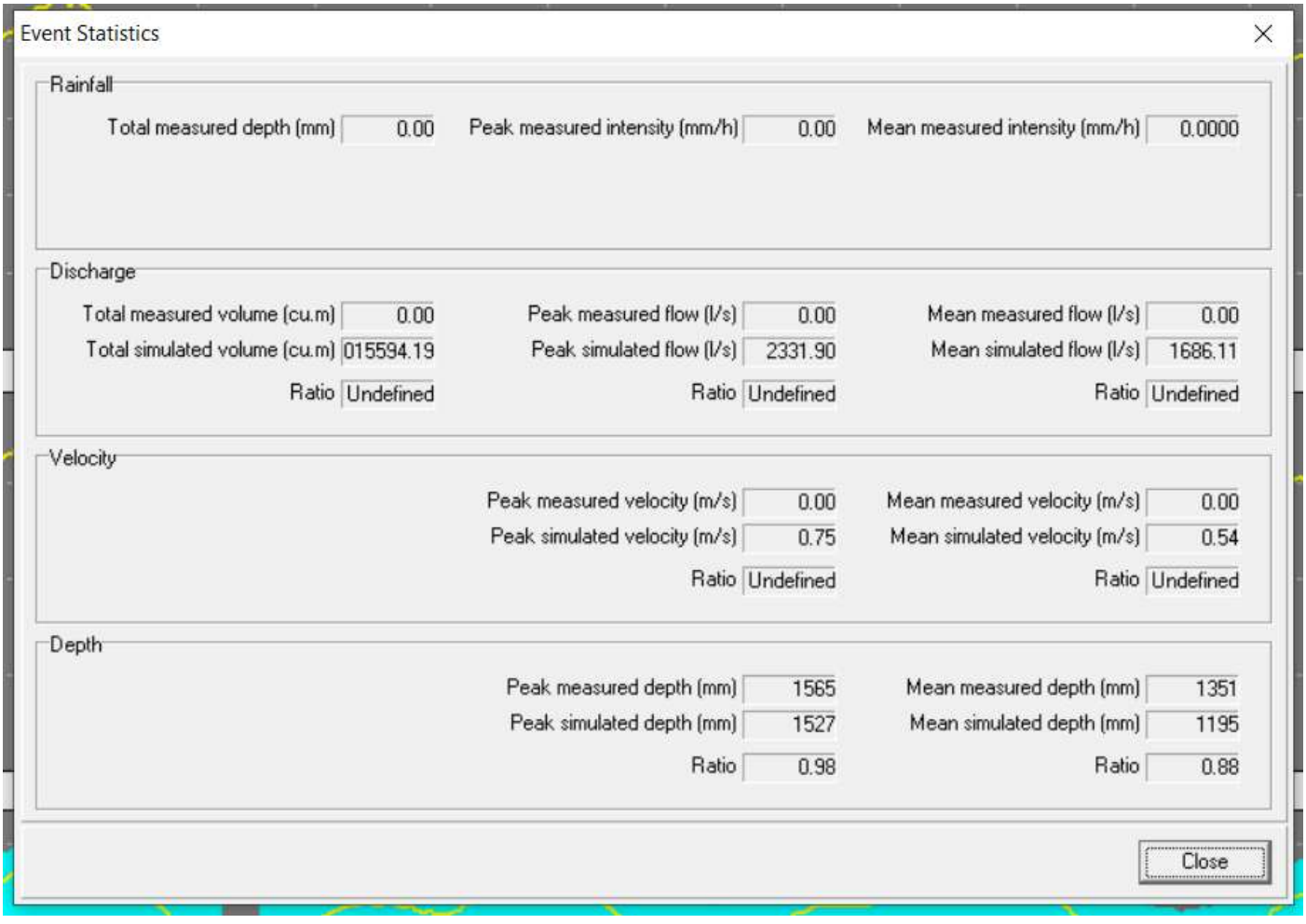
802064 DW2


Gauges | Events | Hydrographs | Scattergraphs | Statistics | Log
Event
2025
DW1
DW2
DW3
Flow Gauge
802063
802064
802065
802310
Rain Gauge
802049R
802051R
802053R
802303R
Build
Statistics
Options
Print
Print All
Zoom
Zoom Extents
Close
Rainfall (mm/h)
Discharge (l/s)
Velocity (m/s)
Depth (mm)
Time (h)
29/09/2025
Measured
Simulated
5/10/2025

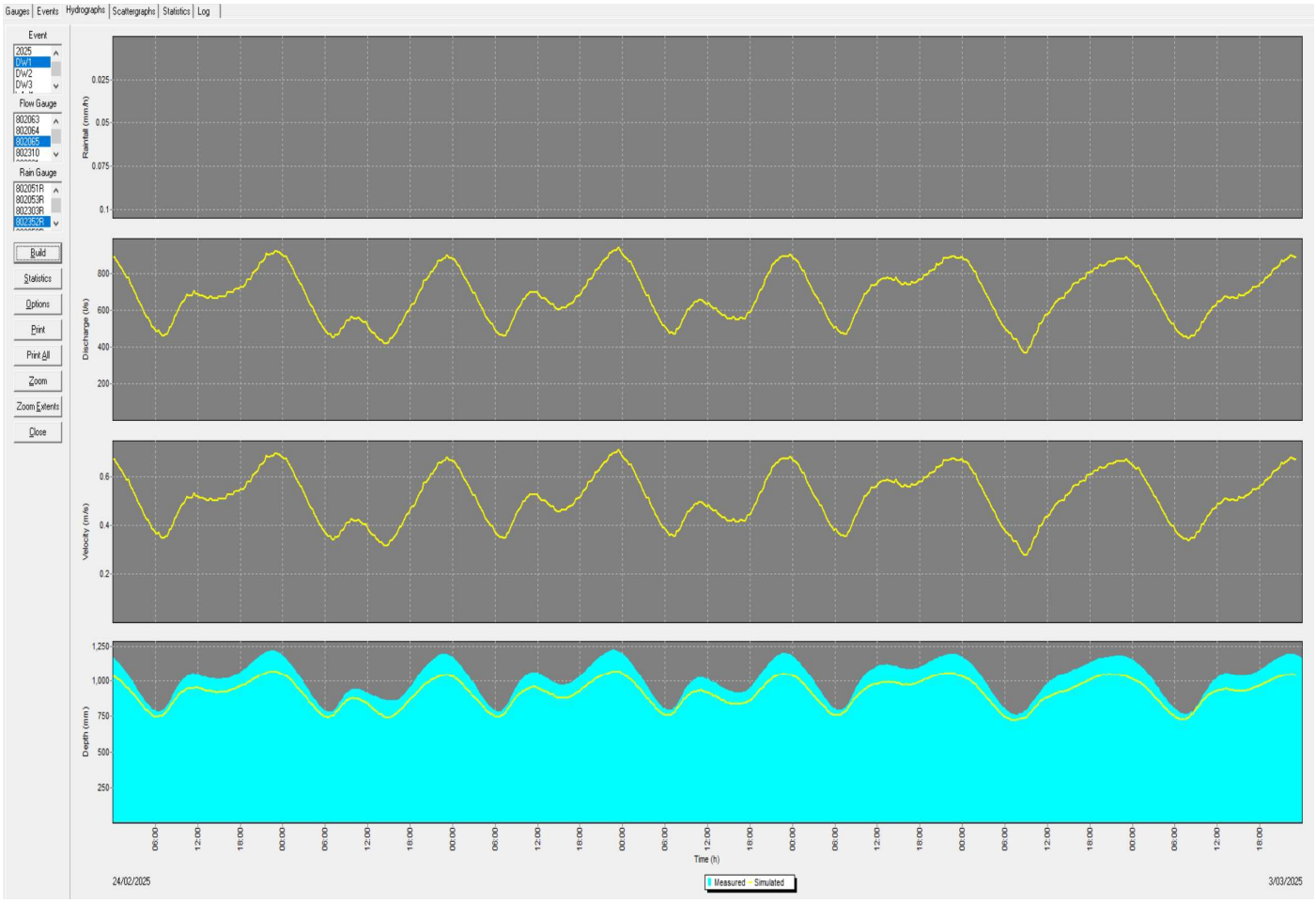

Event Statistics
Rainfall
Total measured depth (mm) 0.40
Peak measured intensity (mm/h) 1.44
Mean measured intensity (mm/h) 0.0024
Discharge
Total measured volume (cu.m) 0.00
Total simulated volume (cu.m) 922401.87
Ratio Undefined
Peak measured flow (l/s) 0.00
Peak simulated flow (l/s) 2003.20
Ratio Undefined
Mean measured flow (l/s) 0.00
Mean simulated flow (l/s) 1531.39
Ratio Undefined
Velocity
Peak measured velocity (m/s) 0.00
Peak simulated velocity (m/s) 0.64
Ratio Undefined
Mean measured velocity (m/s) 0.00
Mean simulated velocity (m/s) 0.49
Ratio Undefined
Depth
Peak measured depth (mm) 1511
Peak simulated depth (mm) 1358
Ratio 0.90
Mean measured depth (mm) 1355
Mean simulated depth (mm) 1113
Ratio 0.82
Close

802064 DW3


Gauges | Events | Hydrographs | Scattergraphs | Statistics | Log
Event
2025
DW1
DW2
DW3
Flow Gauge
802063
802064
802065
802310
Rain Gauge
802049R
802051R
802053R
802303R
Build
Statistics
Options
Print
Print All
Zoom
Zoom Extents
Close
Rainfall (mm/h)
Discharge (l/s)
Velocity (m/s)
Depth (mm)
Time (h)
9/07/2025
Measured
Simulated
16/07/2025

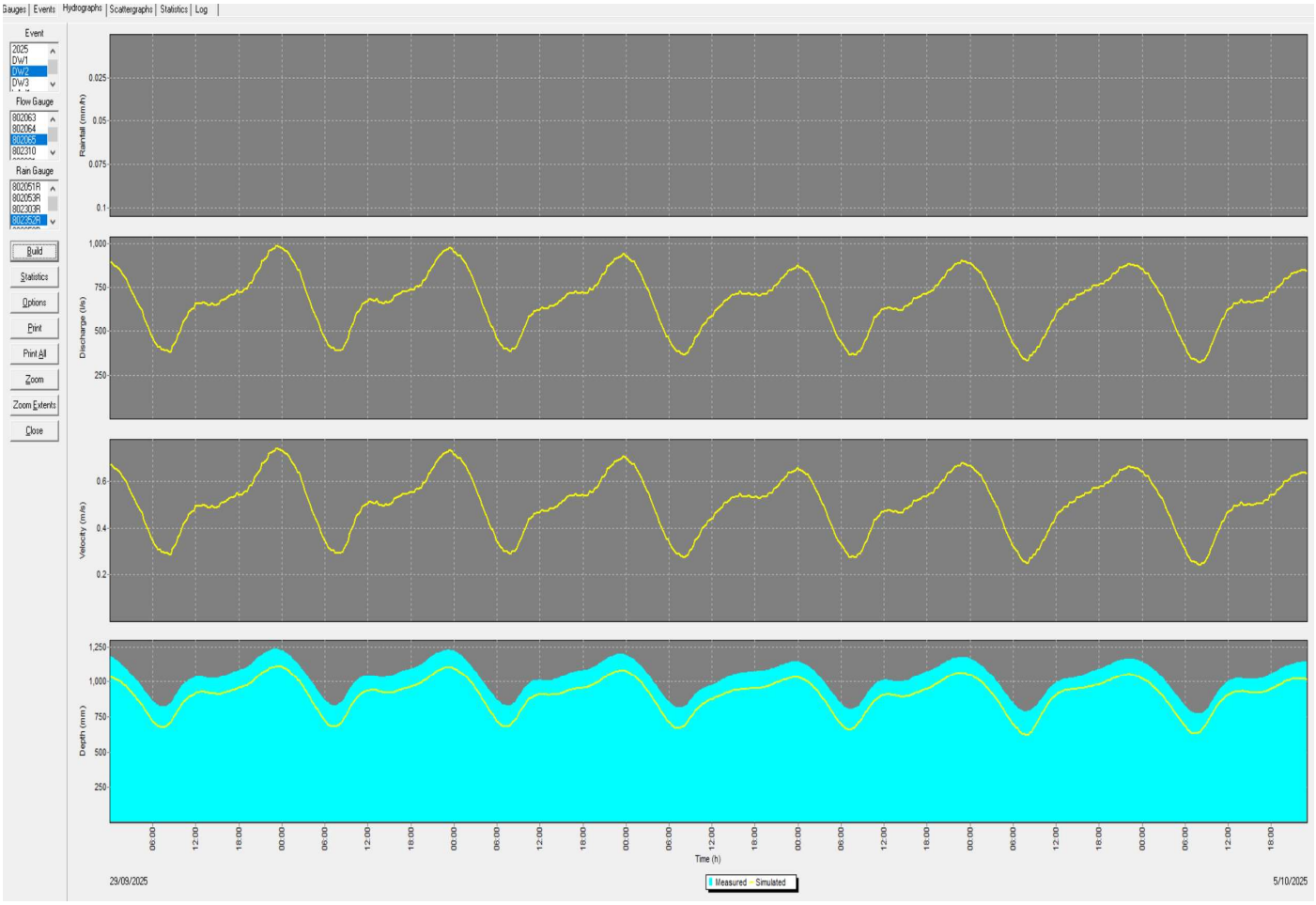

Event Statistics
Rainfall
Total measured depth (mm) 0.00
Peak measured intensity (mm/h) 0.00
Mean measured intensity (mm/h) 0.0000
Discharge
Total measured volume (cu.m) 0.00
Peak measured flow (l/s) 0.00
Mean measured flow (l/s) 0.00
Total simulated volume (cu.m) 015594.19
Peak simulated flow (l/s) 2331.90
Mean simulated flow (l/s) 1686.11
Ratio Undefined
Ratio Undefined
Ratio Undefined
Velocity
Peak measured velocity (m/s) 0.00
Mean measured velocity (m/s) 0.00
Peak simulated velocity (m/s) 0.75
Mean simulated velocity (m/s) 0.54
Ratio Undefined
Ratio Undefined
Depth
Peak measured depth (mm) 1565
Mean measured depth (mm) 1351
Peak simulated depth (mm) 1527
Mean simulated depth (mm) 1195
Ratio 0.98
Ratio 0.88
Close

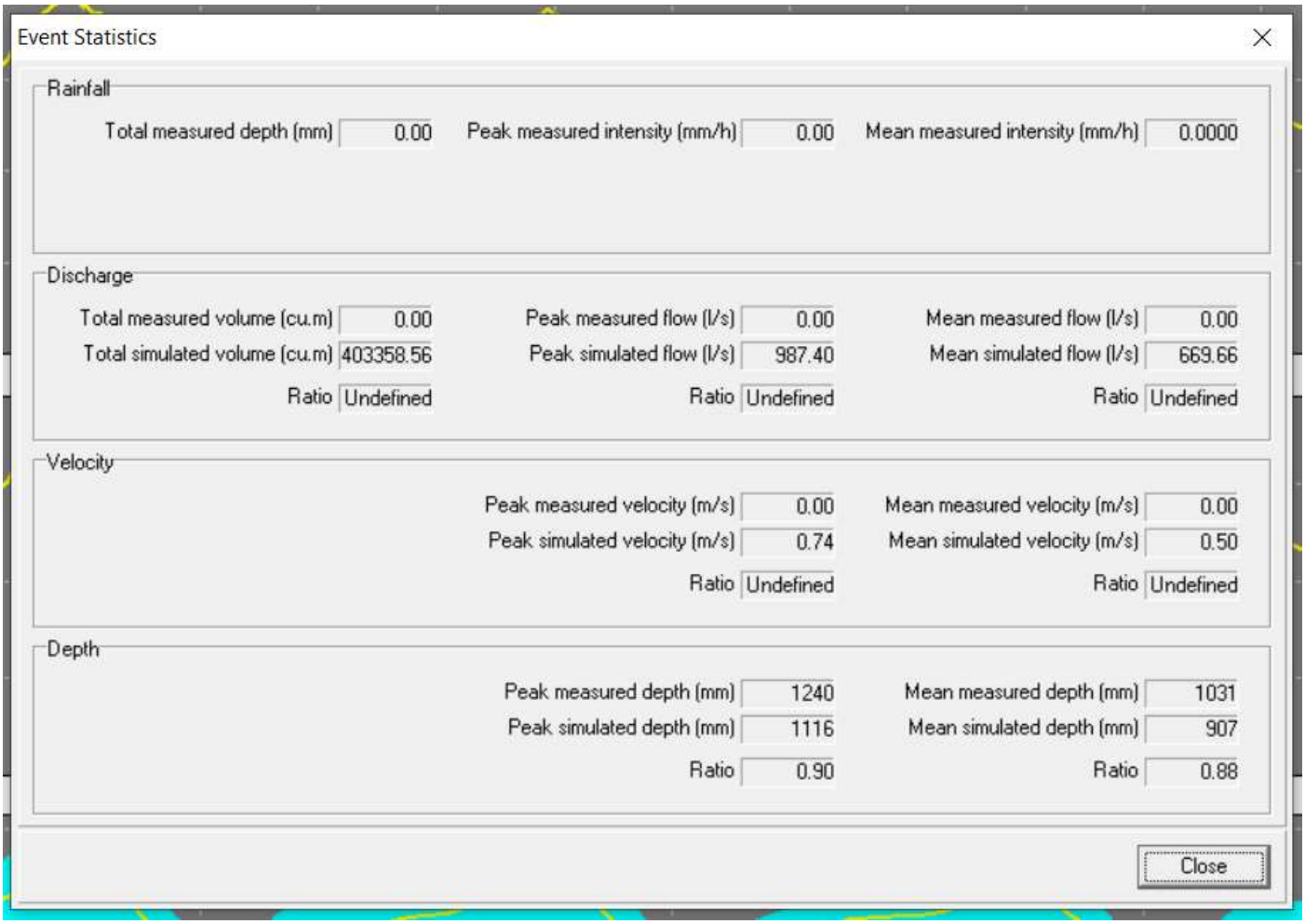
802065 DW1


Gauges | Events | Hydrographs | Scattergraphs | Statistics | Log
Event
2025
DW1
DW2
DW3
Flow Gauge
802063
802064
802065
802310
Rain Gauge
802051R
802053R
802303R
802352R
Build
Statistics
Options
Print
Print All
Zoom
Zoom Extents
Close
Rainfall (mm/h)
Discharge (l/s)
Velocity (m/s)
Depth (mm)
Time (h)
24/02/2025
Measured
Simulated
3/03/2025

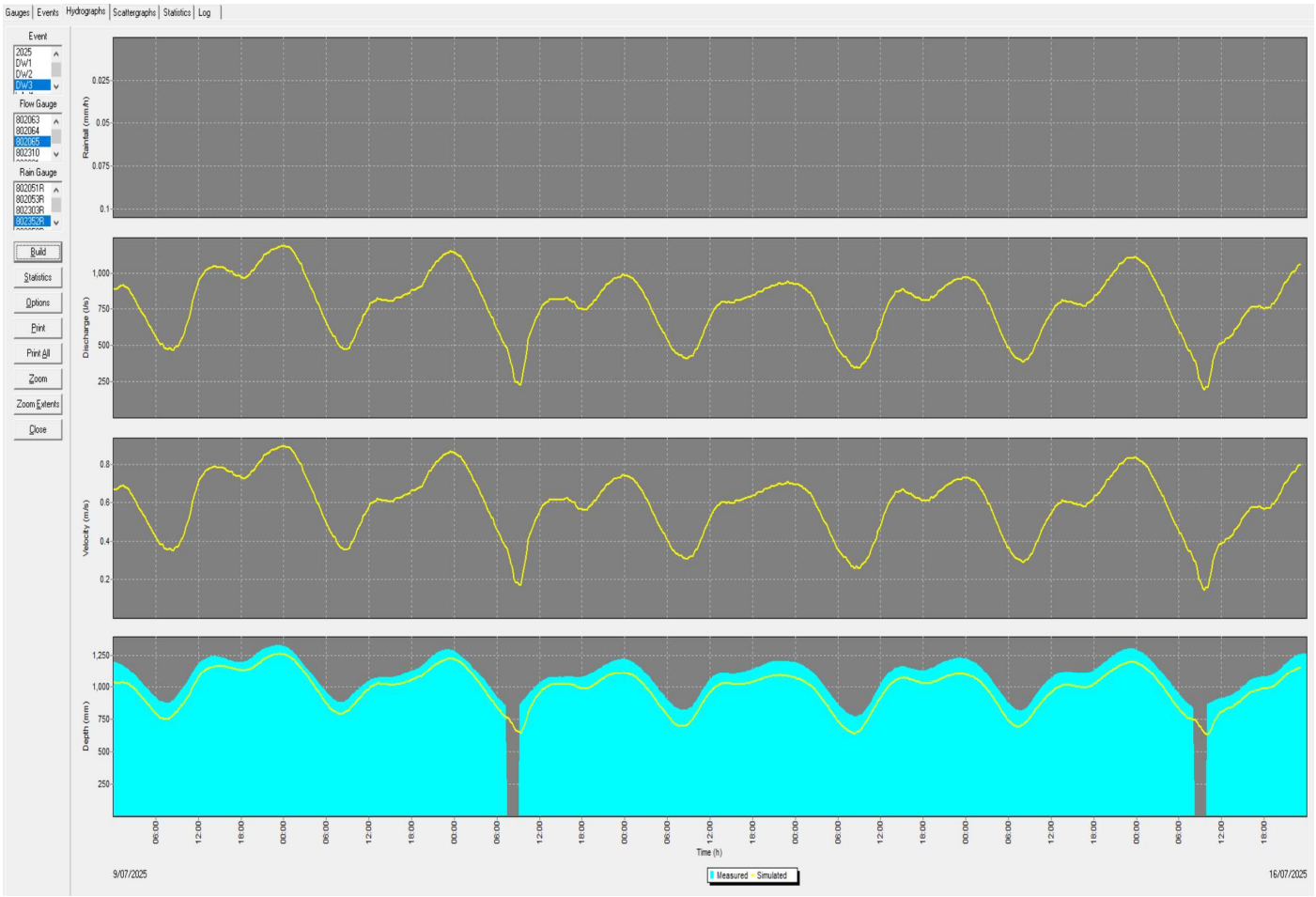

Event Statistics
Rainfall
Total measured depth (mm) 0.00
Peak measured intensity (mm/h) 0.00
Mean measured intensity (mm/h) 0.0000
Discharge
Total measured volume (cu.m) 0.00
Peak measured flow (l/s) 0.00
Mean measured flow (l/s) 0.00
Total simulated volume (cu.m) 411096.70
Peak simulated flow (l/s) 944.70
Mean simulated flow (l/s) 682.51
Ratio Undefined
Ratio Undefined
Ratio Undefined
Velocity
Peak measured velocity (m/s) 0.00
Mean measured velocity (m/s) 0.00
Peak simulated velocity (m/s) 0.71
Mean simulated velocity (m/s) 0.51
Ratio Undefined
Ratio Undefined
Depth
Peak measured depth (mm) 1226
Mean measured depth (mm) 1016
Peak simulated depth (mm) 1072
Mean simulated depth (mm) 917
Ratio 0.87
Ratio 0.90
Close

802065 DW2


Gauges | Events | Hydrographs | Scattergraphs | Statistics | Log
Event
2025
DW1
DW2
DW3
Flow Gauge
802063
802064
802065
802310
Rain Gauge
802051R
802053R
802303R
802305R
Build
Statistics
Options
Print
Print All
Zoom
Zoom Extents
Close
Rainfall (mm/h)
Discharge (l/s)
Velocity (m/s)
Depth (mm)
Time (h)
29/09/2025
Measured
Simulated
5/10/2025

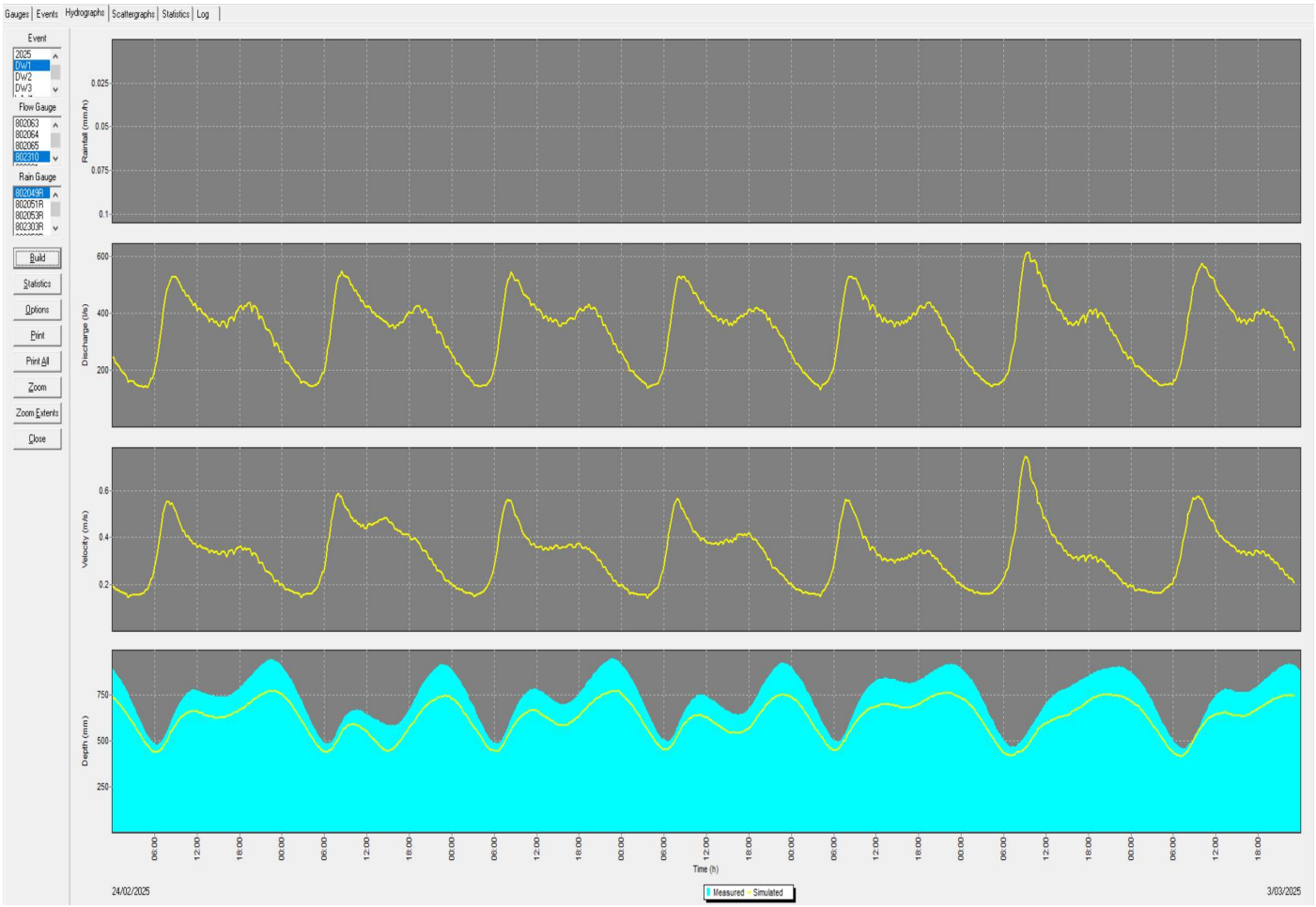

Event Statistics
Rainfall
Total measured depth (mm) 0.00
Peak measured intensity (mm/h) 0.00
Mean measured intensity (mm/h) 0.0000
Discharge
Total measured volume (cu.m) 0.00
Peak measured flow (l/s) 0.00
Mean measured flow (l/s) 0.00
Total simulated volume (cu.m) 403358.56
Peak simulated flow (l/s) 987.40
Mean simulated flow (l/s) 669.66
Ratio Undefined
Ratio Undefined
Ratio Undefined
Velocity
Peak measured velocity (m/s) 0.00
Mean measured velocity (m/s) 0.00
Peak simulated velocity (m/s) 0.74
Mean simulated velocity (m/s) 0.50
Ratio Undefined
Ratio Undefined
Depth
Peak measured depth (mm) 1240
Mean measured depth (mm) 1031
Peak simulated depth (mm) 1116
Mean simulated depth (mm) 907
Ratio 0.90
Ratio 0.88
Close

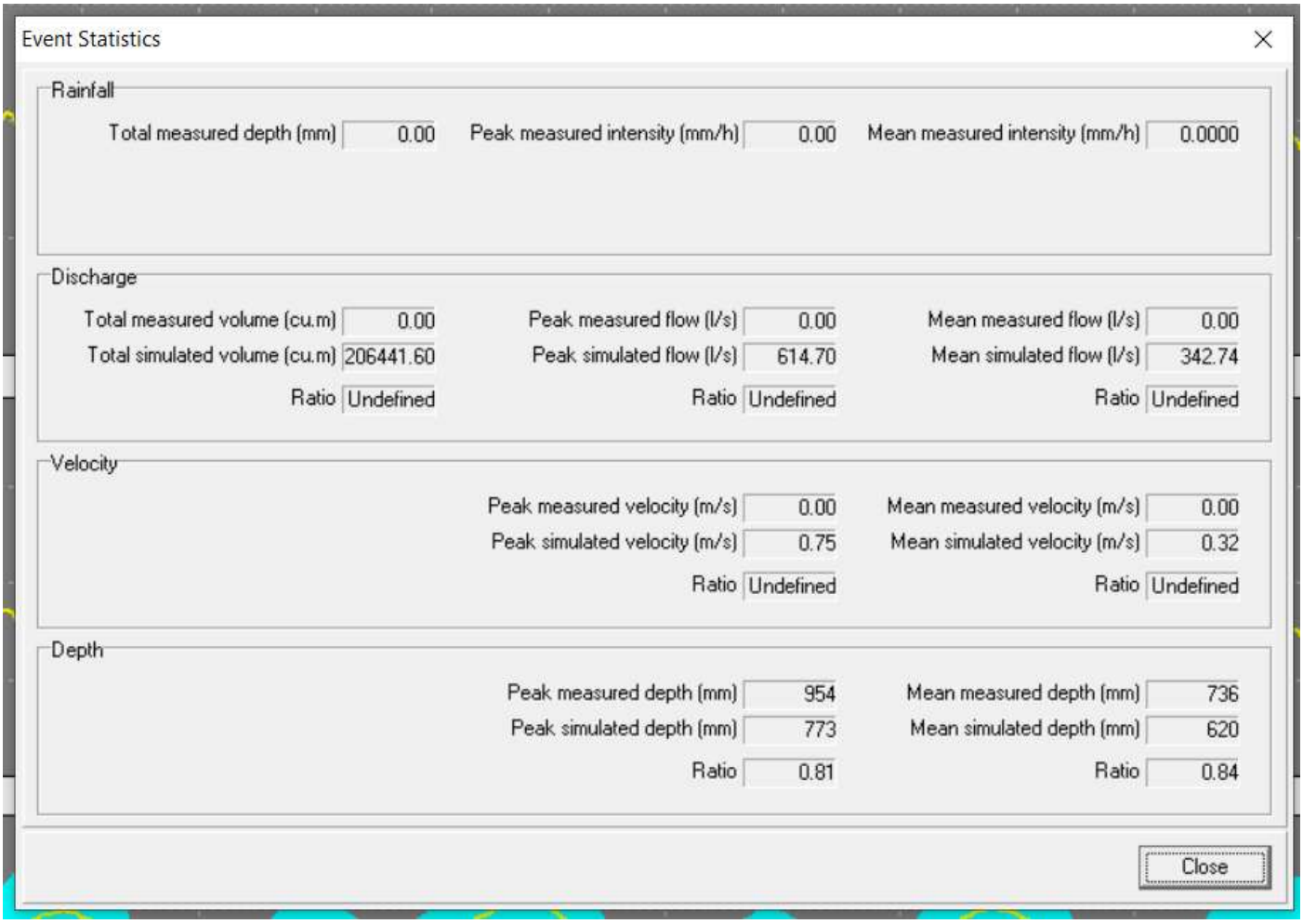
802065 DW3


Gauges | Events | Hydrographs | Scattergraphs | Statistics | Log
Event
2025
DW1
DW2
DW3
Flow Gauge
802063
802064
802065
802910
Rain Gauge
802051R
802053R
802303R
802352R
Build
Statistics
Options
Print
Print All
Zoom
Zoom Extents
Close
Rainfall (mm/h)
Discharge (l/s)
Velocity (m/s)
Depth (mm)
Time (h)
9/07/2025
Measured
Simulated
16/07/2025

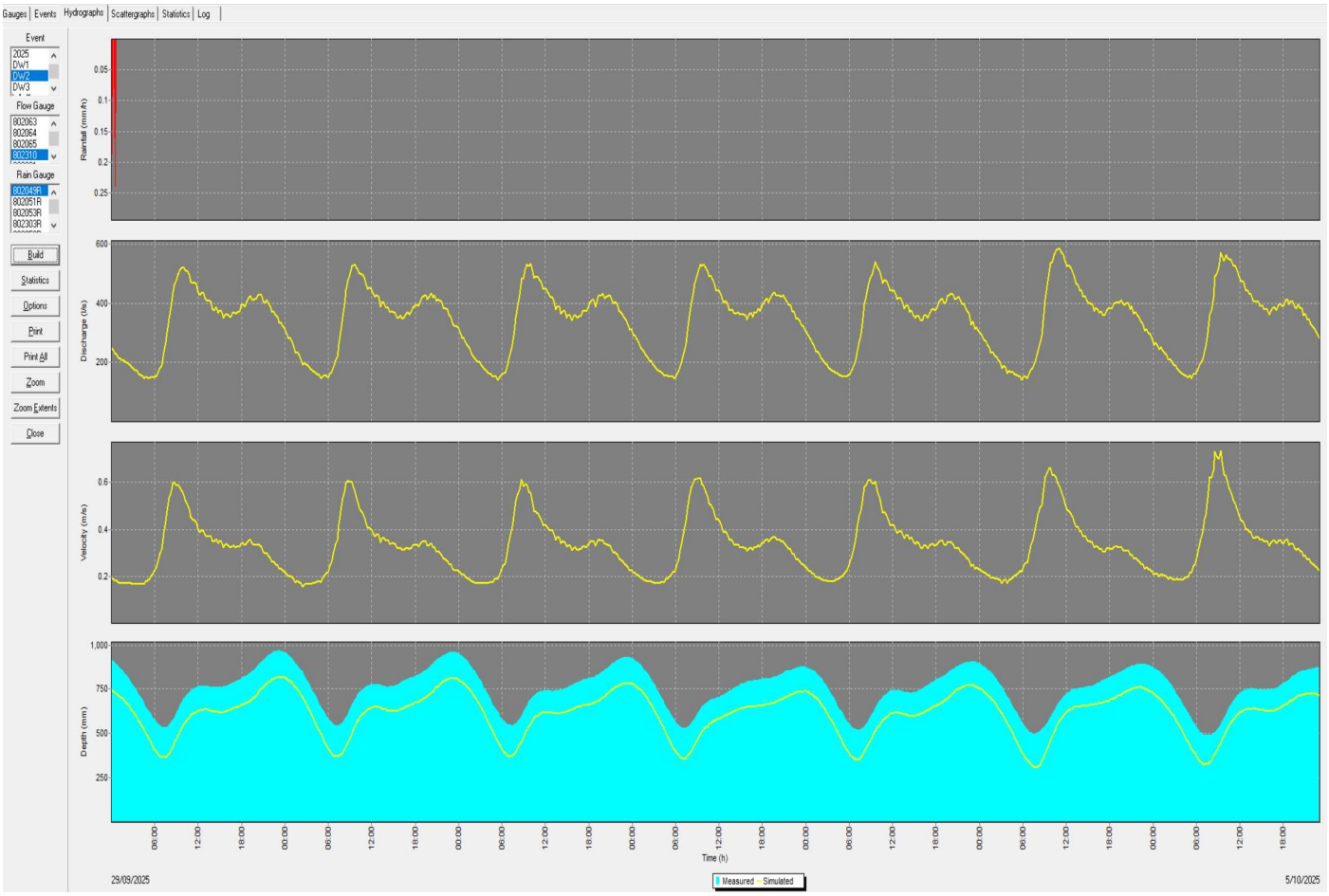

Event Statistics
Rainfall
Total measured depth (mm) 0.00
Peak measured intensity (mm/h) 0.00
Mean measured intensity (mm/h) 0.0000
Discharge
Total measured volume (cu.m) 0.00
Peak measured flow (l/s) 0.00
Mean measured flow (l/s) 0.00
Total simulated volume (cu.m) 468049.88
Peak simulated flow (l/s) 1183.20
Mean simulated flow (l/s) 777.07
Ratio Undefined
Ratio Undefined
Ratio Undefined
Velocity
Peak measured velocity (m/s) 0.00
Mean measured velocity (m/s) 0.00
Peak simulated velocity (m/s) 0.89
Mean simulated velocity (m/s) 0.58
Ratio Undefined
Ratio Undefined
Depth
Peak measured depth (mm) 1329
Mean measured depth (mm) 1065
Peak simulated depth (mm) 1261
Mean simulated depth (mm) 980
Ratio 0.95
Ratio 0.92
Close

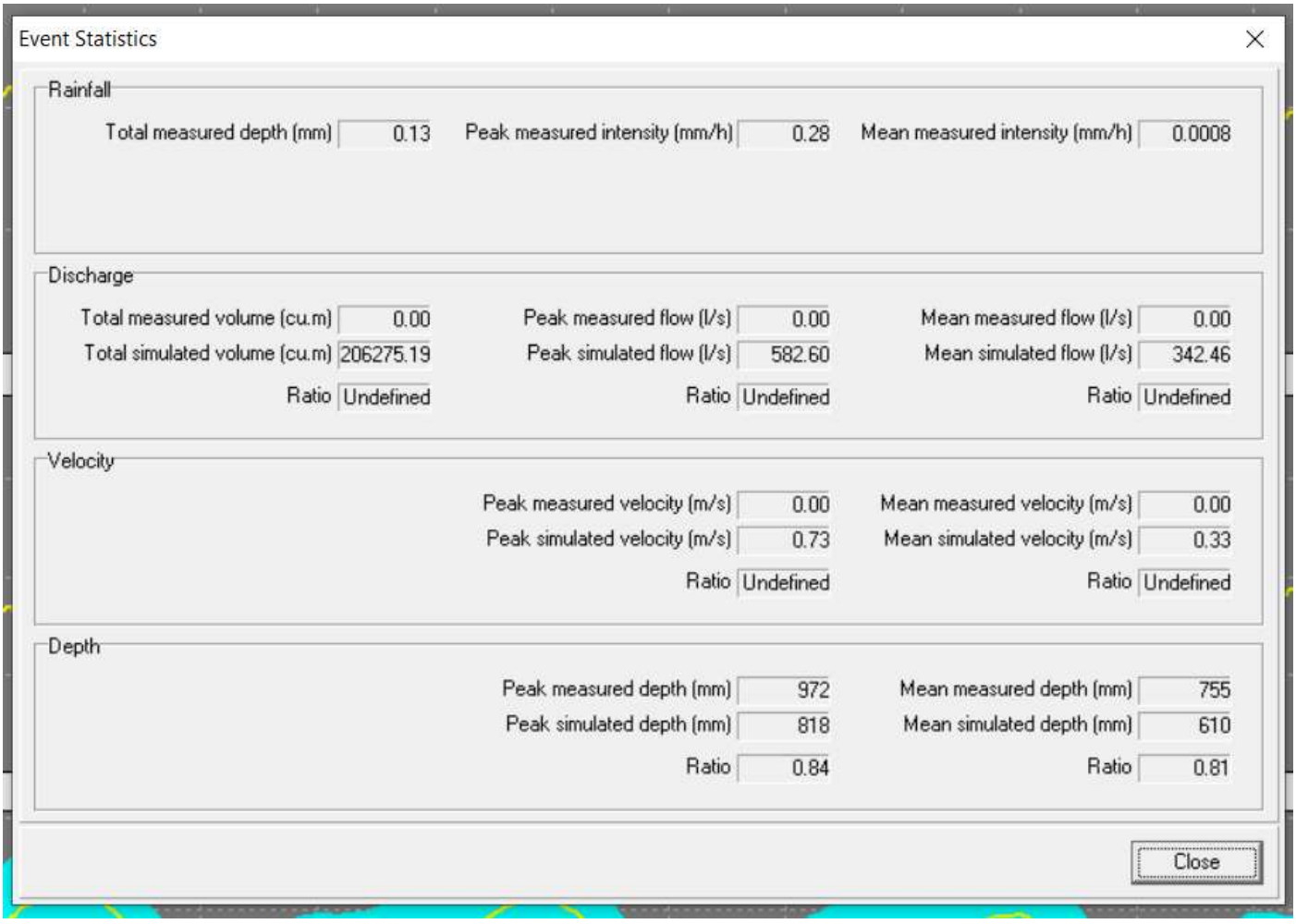
802310 DW1


Gauges | Events | Hydrographs | Scattergraphs | Statistics | Log
Event
2025
DW1
DW2
DW3
Flow Gauge
802063
802064
802065
802310
Rain Gauge
802049R
802051R
802053R
802303R
Build
Statistics
Options
Print
Print All
Zoom
Zoom Extents
Close
Rainfall (mm/h)
Discharge (l/s)
Velocity (m/s)
Depth (mm)
Time (h)
24/02/2025
Measured
Simulated
3/03/2025

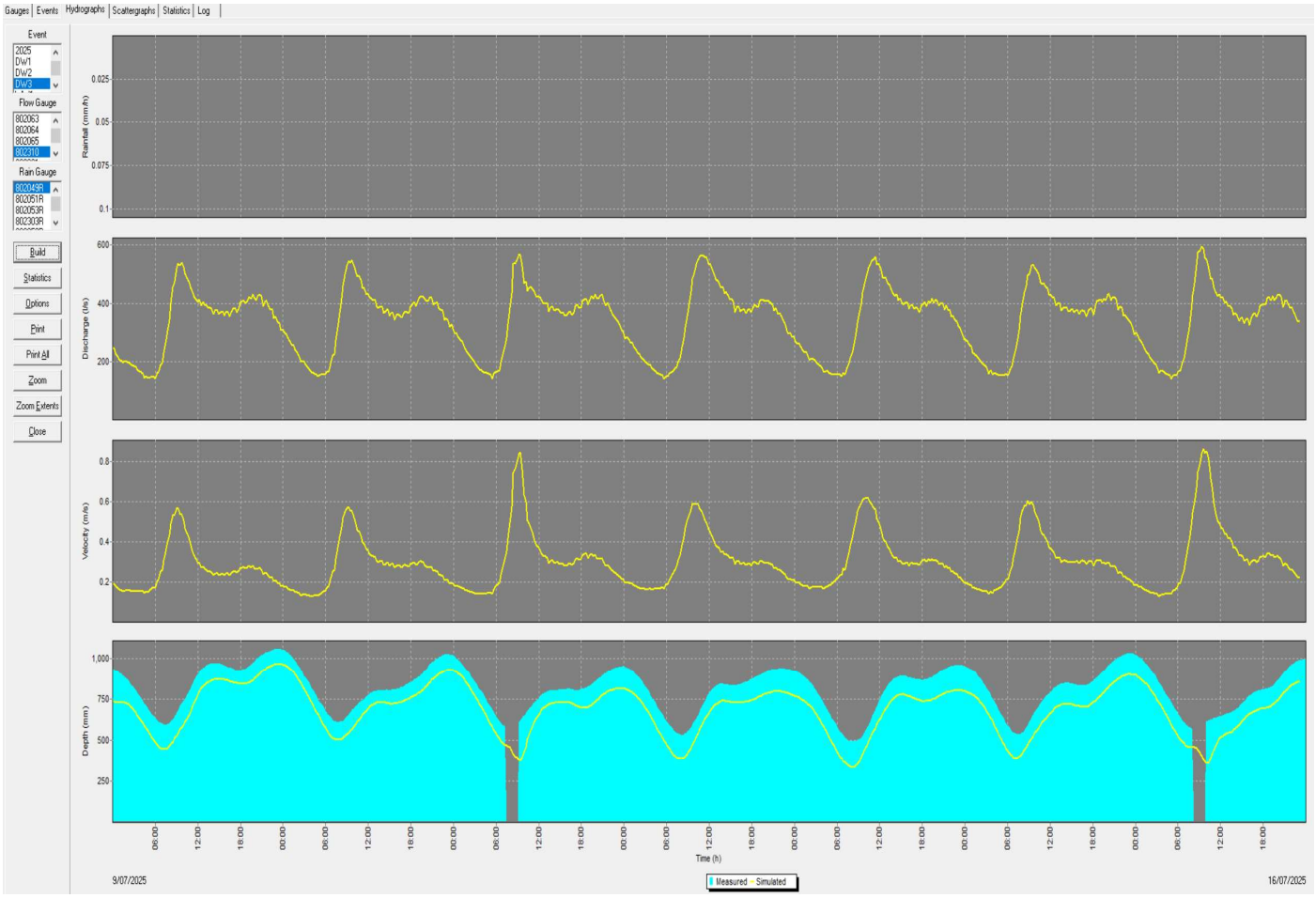

Event Statistics
Rainfall
Total measured depth (mm) 0.00
Peak measured intensity (mm/h) 0.00
Mean measured intensity (mm/h) 0.0000
Discharge
Total measured volume (cu.m) 0.00
Peak measured flow (l/s) 0.00
Mean measured flow (l/s) 0.00
Total simulated volume (cu.m) 206441.60
Peak simulated flow (l/s) 614.70
Mean simulated flow (l/s) 342.74
Ratio Undefined
Ratio Undefined
Ratio Undefined
Velocity
Peak measured velocity (m/s) 0.00
Mean measured velocity (m/s) 0.00
Peak simulated velocity (m/s) 0.75
Mean simulated velocity (m/s) 0.32
Ratio Undefined
Ratio Undefined
Depth
Peak measured depth (mm) 954
Mean measured depth (mm) 736
Peak simulated depth (mm) 773
Mean simulated depth (mm) 620
Ratio 0.81
Ratio 0.84
Close

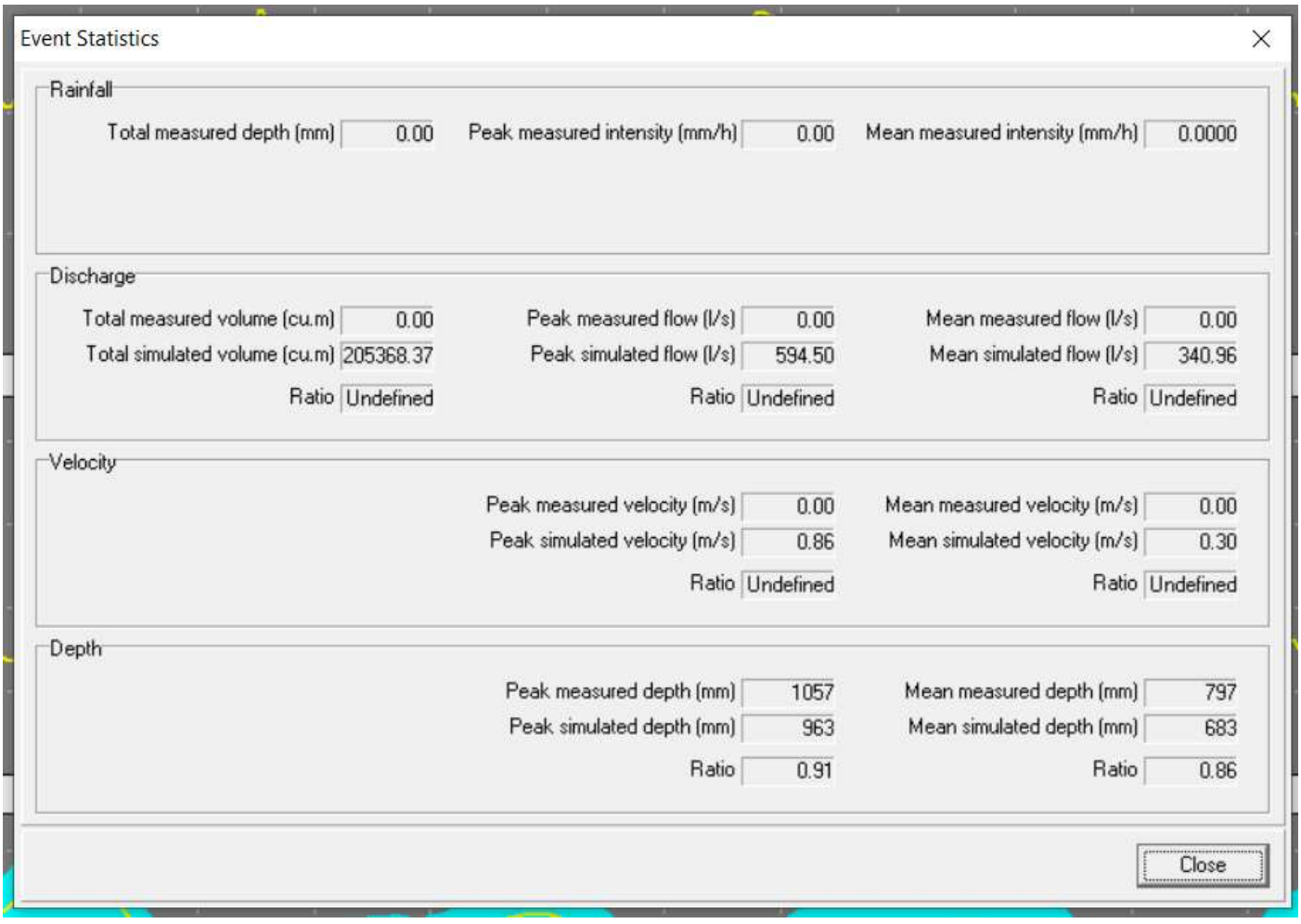
802310 DW2


Gauges
Events
Hydrographs
Scattergraphs
Statistics
Log
Event
2025
DW1
DW2
DW3
Flow Gauge
802063
802064
802065
802310
Rain Gauge
802049R
802051R
802053R
802303R
Build
Statistics
Options
Print
Print All
Zoom
Zoom Extents
Close
Rainfall (mm/h)
Discharge (l/s)
Velocity (m/s)
Depth (mm)
Time (h)
29/09/2025
Measured
Simulated
5/10/2025


Event Statistics
Rainfall
Total measured depth (mm) 0.13
Peak measured intensity (mm/h) 0.28
Mean measured intensity (mm/h) 0.0008
Discharge
Total measured volume (cu.m) 0.00
Peak measured flow (l/s) 0.00
Mean measured flow (l/s) 0.00
Total simulated volume (cu.m) 206275.19
Peak simulated flow (l/s) 582.60
Mean simulated flow (l/s) 342.46
Ratio Undefined
Ratio Undefined
Ratio Undefined
Velocity
Peak measured velocity (m/s) 0.00
Mean measured velocity (m/s) 0.00
Peak simulated velocity (m/s) 0.73
Mean simulated velocity (m/s) 0.33
Ratio Undefined
Ratio Undefined
Depth
Peak measured depth (mm) 972
Mean measured depth (mm) 755
Peak simulated depth (mm) 818
Mean simulated depth (mm) 610
Ratio 0.84
Ratio 0.81
Close

802310 DW3


Gauges | Events | Hydrographs | Scattergraphs | Statistics | Log
Event
2025
DW1
DW2
DW3
Flow Gauge
802063
802064
802065
802310
Rain Gauge
802049R
802051R
802053R
802303R
Build
Statistics
Options
Print
Print All
Zoom
Zoom Extents
Close
Rainfall (mm/h)
Discharge (l/s)
Velocity (m/s)
Depth (mm)
Time (h)
9/07/2025
Measured
Simulated
16/07/2025


Event Statistics
Rainfall
Total measured depth (mm) 0.00
Peak measured intensity (mm/h) 0.00
Mean measured intensity (mm/h) 0.0000
Discharge
Total measured volume (cu.m) 0.00
Peak measured flow (l/s) 0.00
Mean measured flow (l/s) 0.00
Total simulated volume (cu.m) 205368.37
Peak simulated flow (l/s) 594.50
Mean simulated flow (l/s) 340.96
Ratio Undefined
Ratio Undefined
Ratio Undefined
Velocity
Peak measured velocity (m/s) 0.00
Mean measured velocity (m/s) 0.00
Peak simulated velocity (m/s) 0.86
Mean simulated velocity (m/s) 0.30
Ratio Undefined
Ratio Undefined
Depth
Peak measured depth (mm) 1057
Mean measured depth (mm) 797
Peak simulated depth (mm) 963
Mean simulated depth (mm) 683
Ratio 0.91
Ratio 0.86
Close

Attachment 3 Calibration Plots – Wet Weather Flow

Calibration Plots Botany Bay Catchment _ Malabar System 2025

Wet Weather Events:

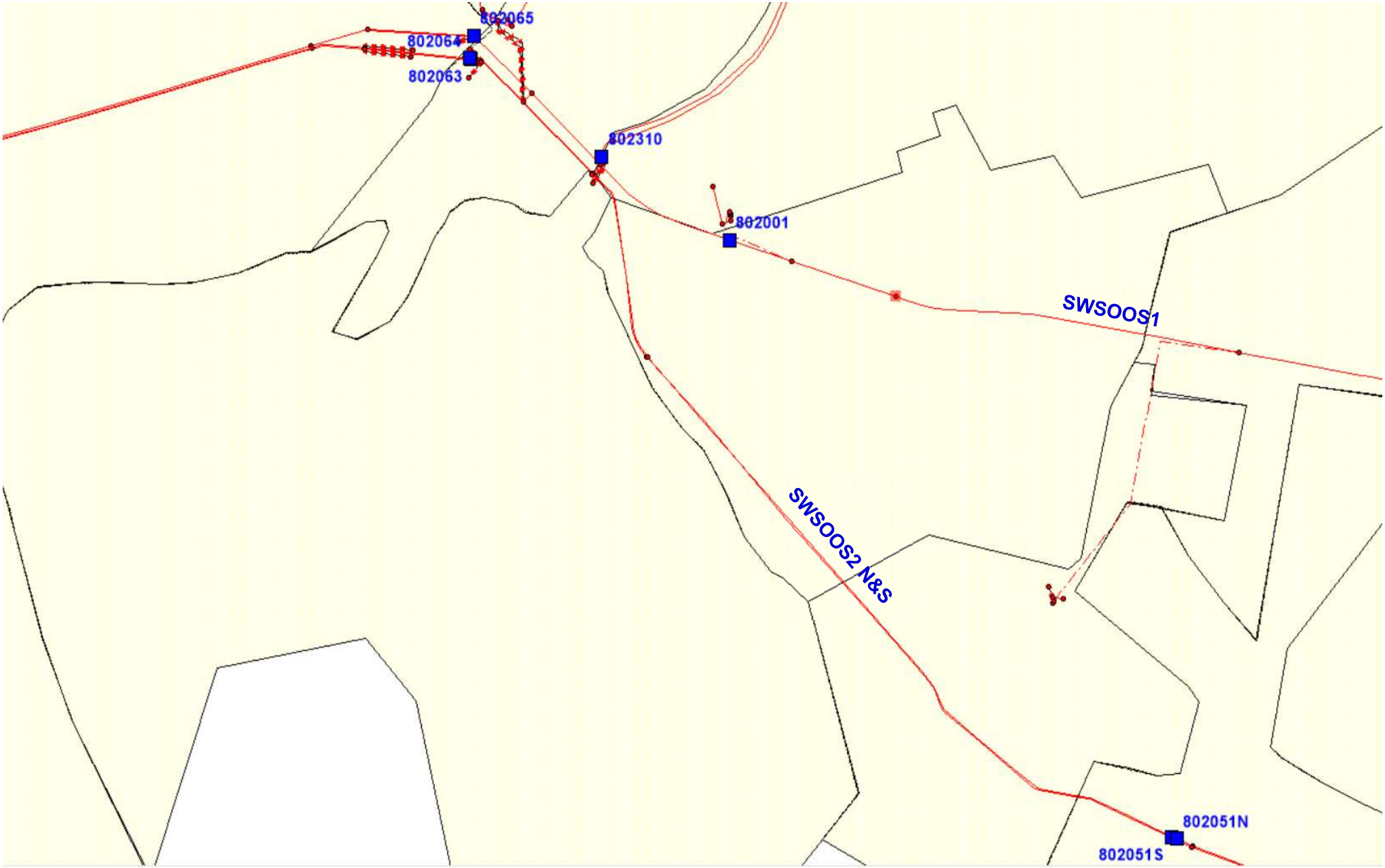
WW Event 1 : 25/07 - 31/08/2025 (Three Rain Periods covered)

WW Event 2 : 16/03 - 11/04/2025 (Three Rain Periods covered)

WW Event 3 : 24/01 - 16 / 03 / 2025 (Three Rain Periods covered)

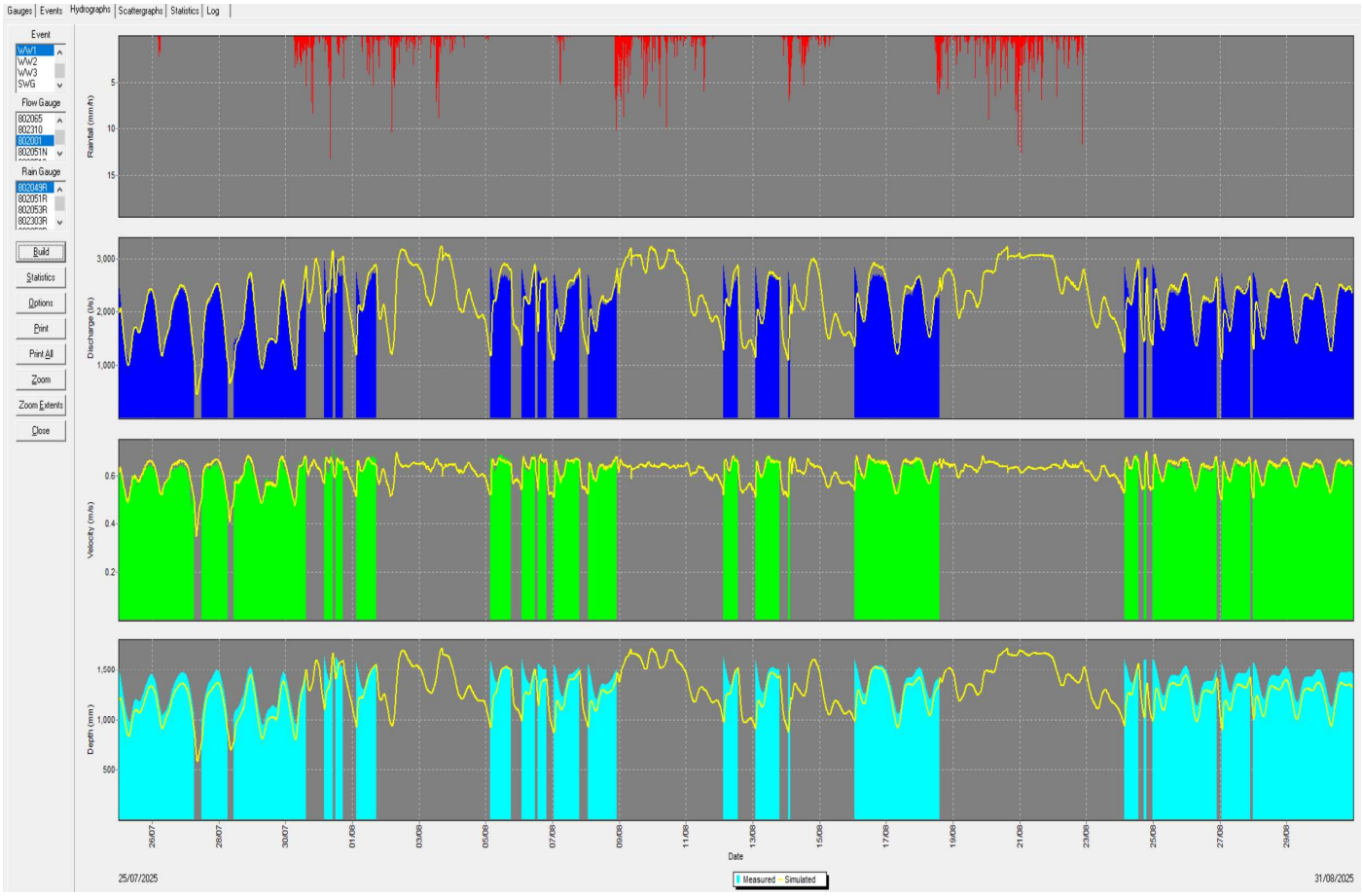
Gauges Assessed:

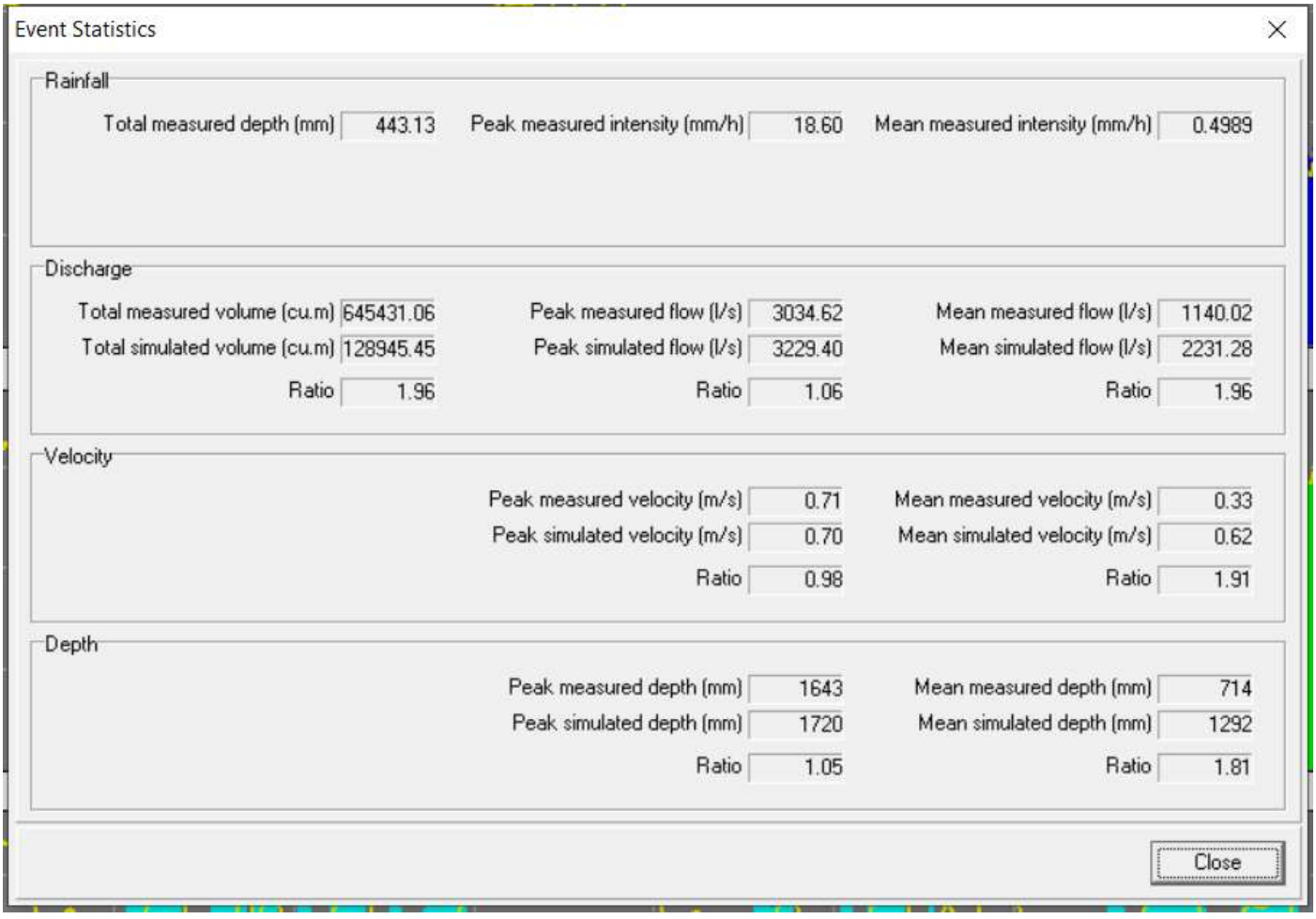
Gauge	Comment
802001	SWSOOS 1, HVQ Licence Gauge
802051N	SWSOOS2 N, HVQ Licence Gauge
802051S	SWSOOS2 S, HVQ Licence Gauge
802063	SWSOOS 2S (S2.SYP2), Level Only, Licence Gauge
802064	SWSOOS 2N (N2.SYP2), Level Only, Licence Gauge
802065	SWSOOS 1 (T3.SYP2), Level Only, Licence Gauge
802310	Southern Division Sewer, Level Only, Licence Gauge



Sewer Gauge Layout – Botany Bay Catchment

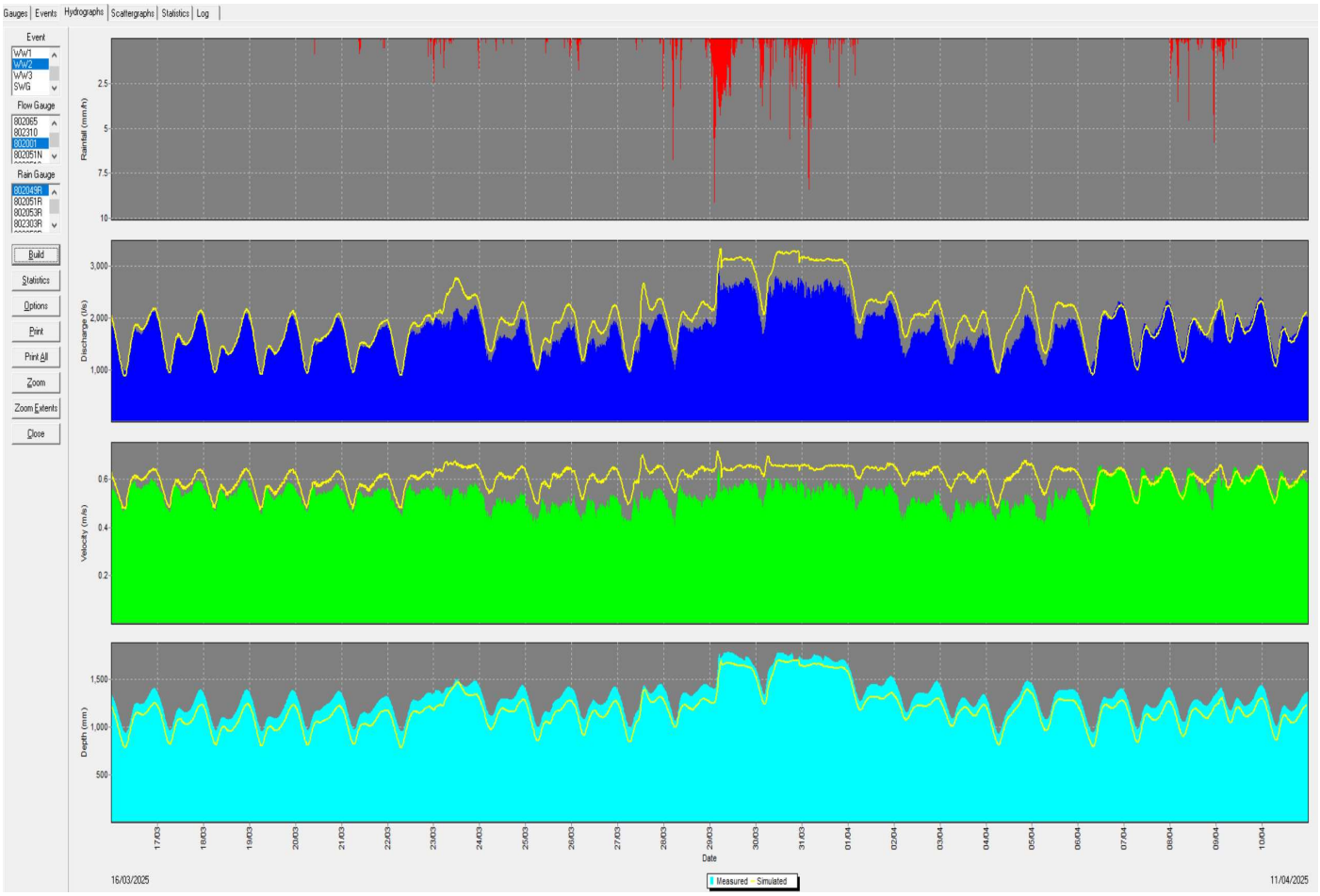
802001 WW1

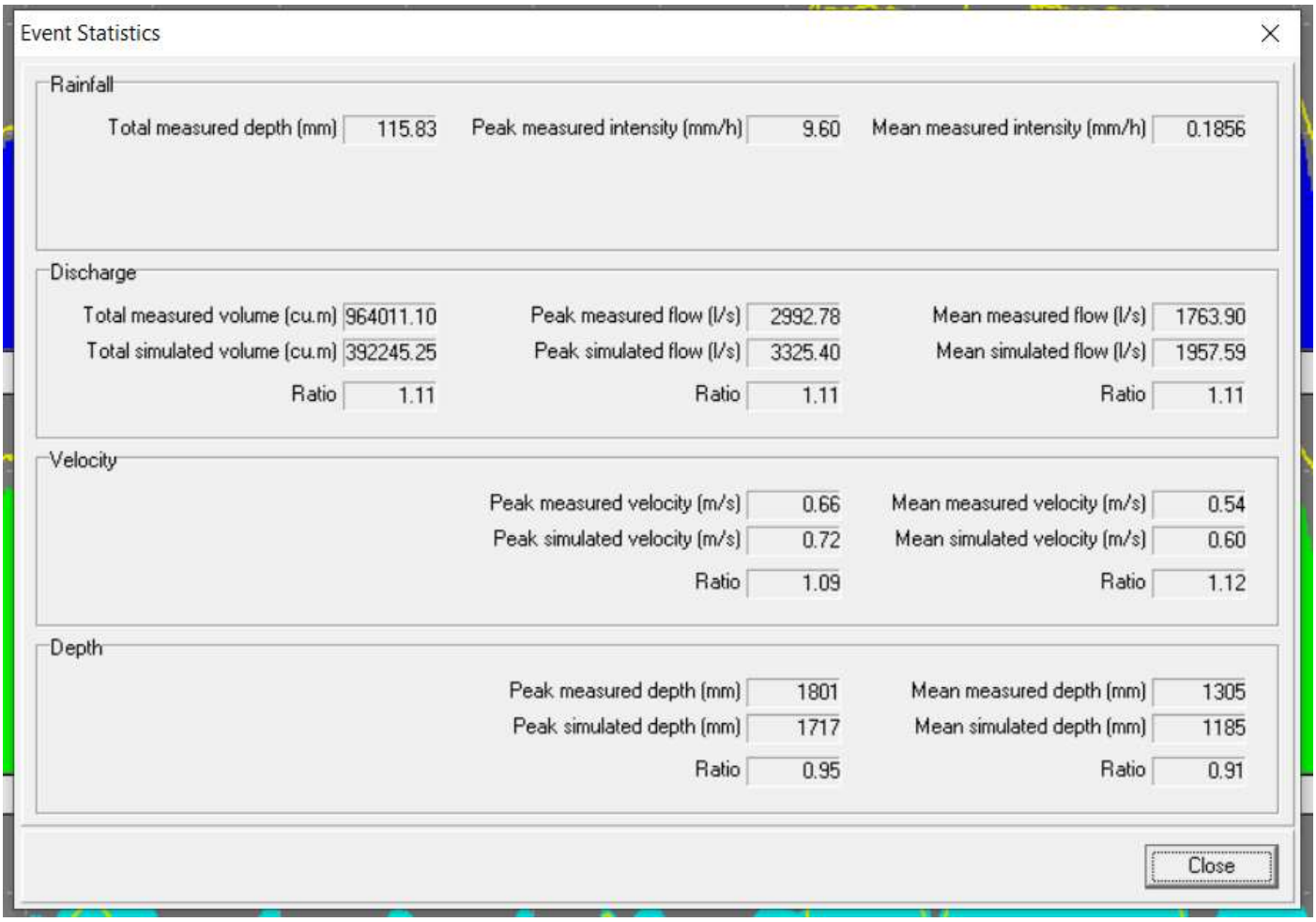




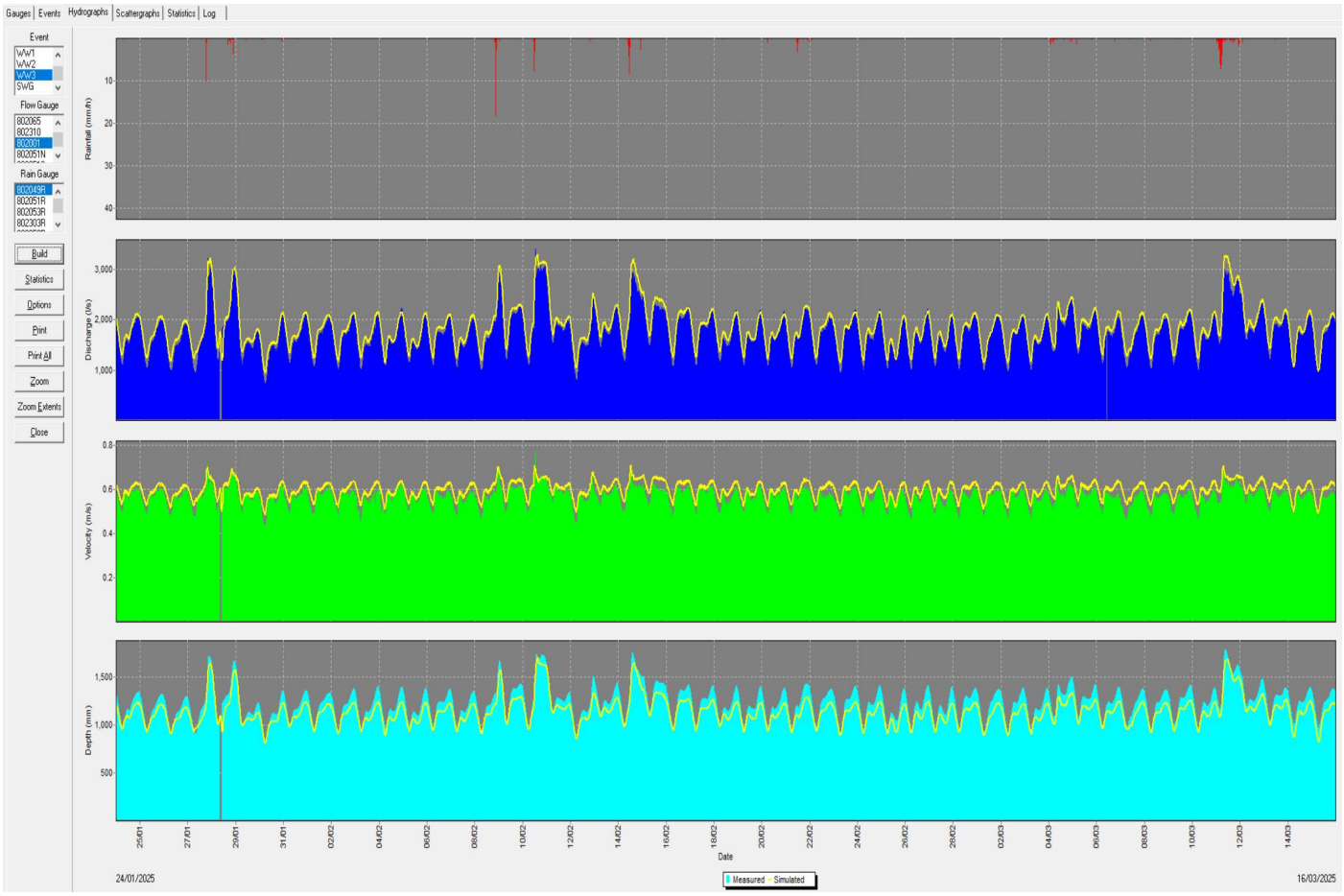
Due to Missing Gauge Data, the Statistics Average couldn’t be evaluated.

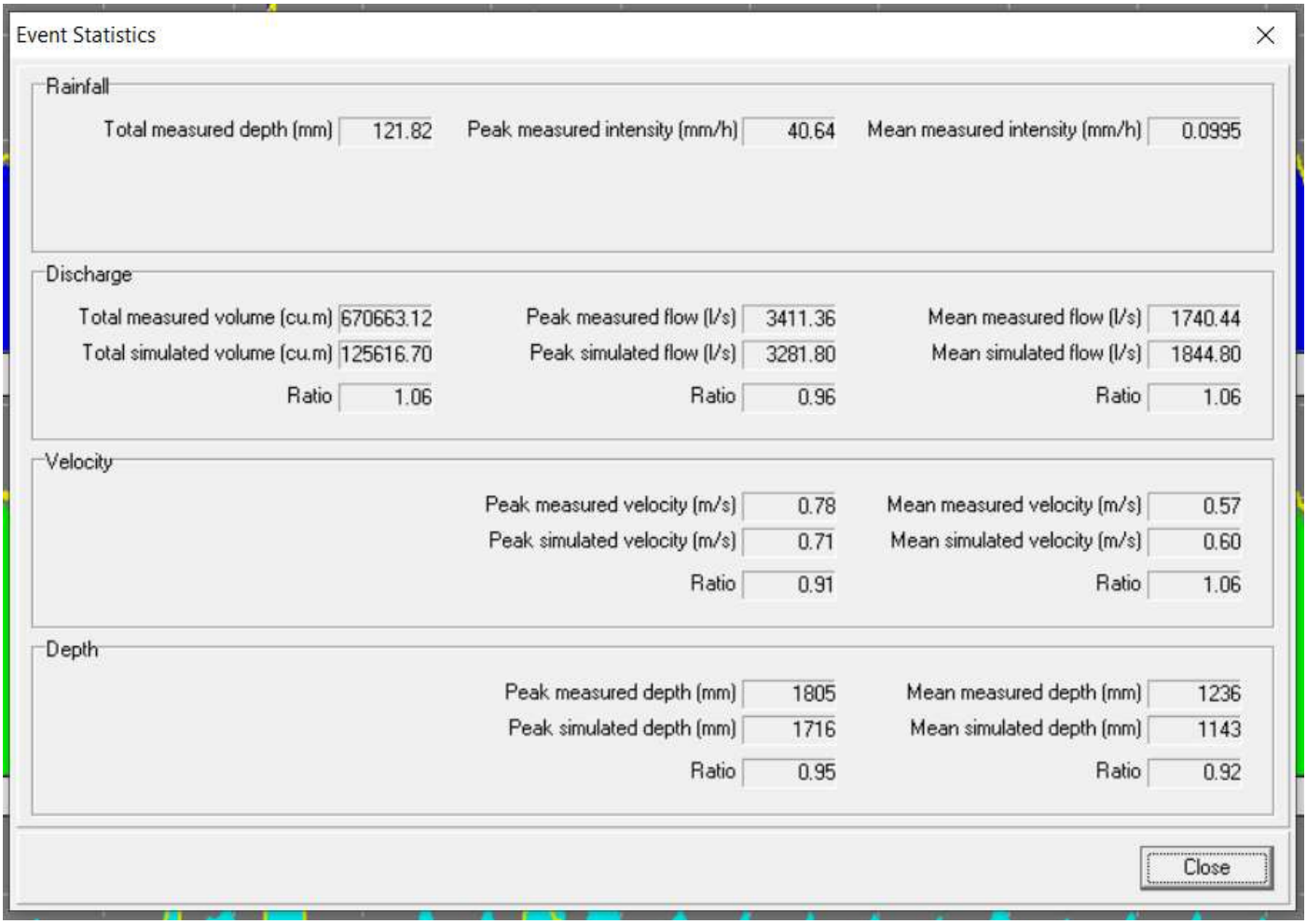
802001 WW2


Gauges
Events
Hydrographs
Scattergraphs
Statistics
Log
Event
WW1
WW2
WW3
SWG
Flow Gauge
802065
802310
802001
802051N
Rain Gauge
802049R
802051R
802053R
802303R
Build
Statistics
Options
Print
Print All
Zoom
Zoom Extents
Close
Rainfall (mm/h)
Discharge (l/s)
Velocity (m/s)
Depth (mm)
Date
16/03/2025
11/04/2025
Measured
Simulated

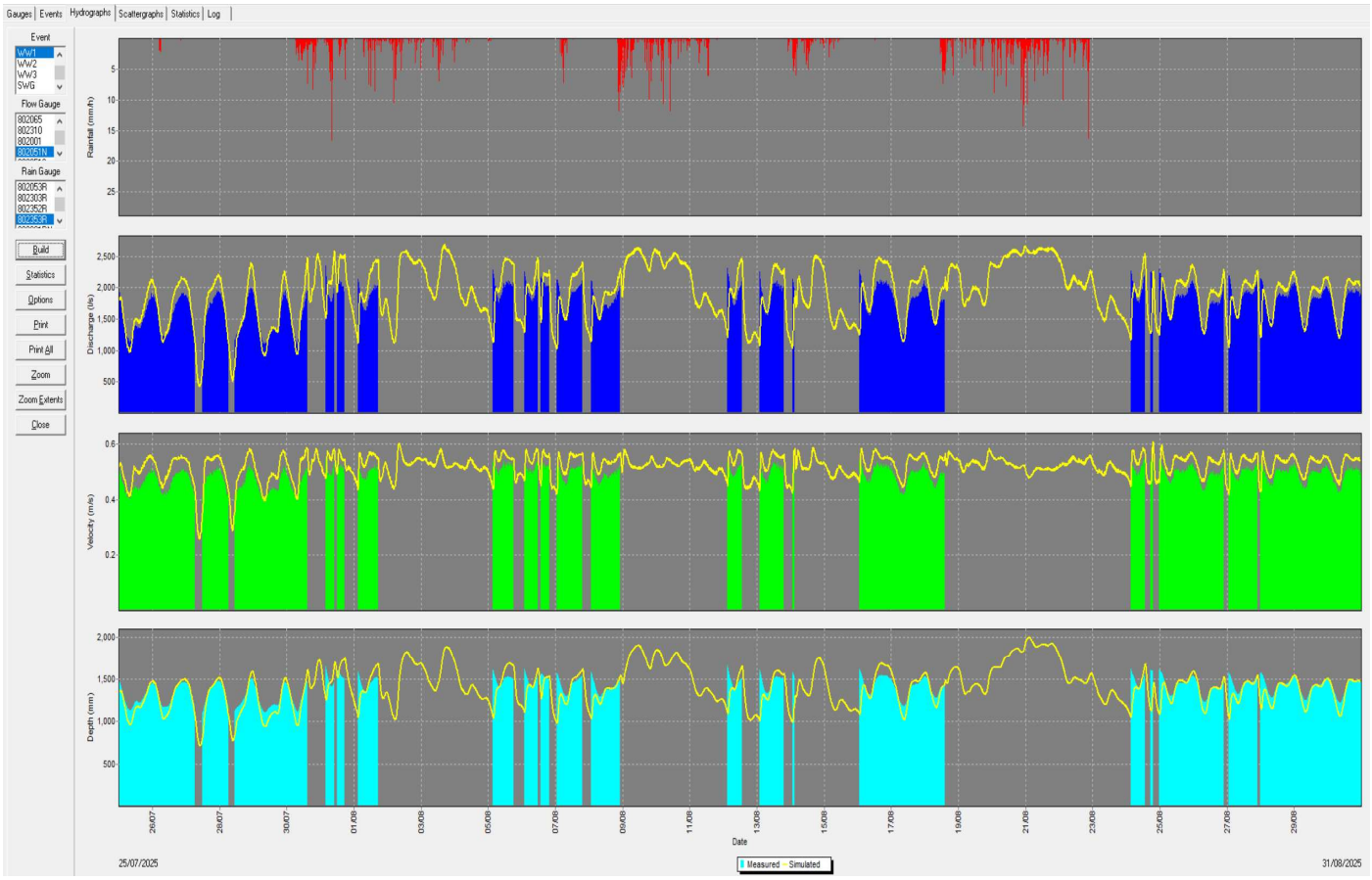

Event Statistics
Rainfall
Total measured depth (mm) 115.83
Peak measured intensity (mm/h) 9.60
Mean measured intensity (mm/h) 0.1856
Discharge
Total measured volume (cu.m) 964011.10
Peak measured flow (l/s) 2992.78
Mean measured flow (l/s) 1763.90
Total simulated volume (cu.m) 392245.25
Peak simulated flow (l/s) 3325.40
Mean simulated flow (l/s) 1957.59
Ratio 1.11
Ratio 1.11
Ratio 1.11
Velocity
Peak measured velocity (m/s) 0.66
Mean measured velocity (m/s) 0.54
Peak simulated velocity (m/s) 0.72
Mean simulated velocity (m/s) 0.60
Ratio 1.09
Ratio 1.12
Depth
Peak measured depth (mm) 1801
Mean measured depth (mm) 1305
Peak simulated depth (mm) 1717
Mean simulated depth (mm) 1185
Ratio 0.95
Ratio 0.91
Close

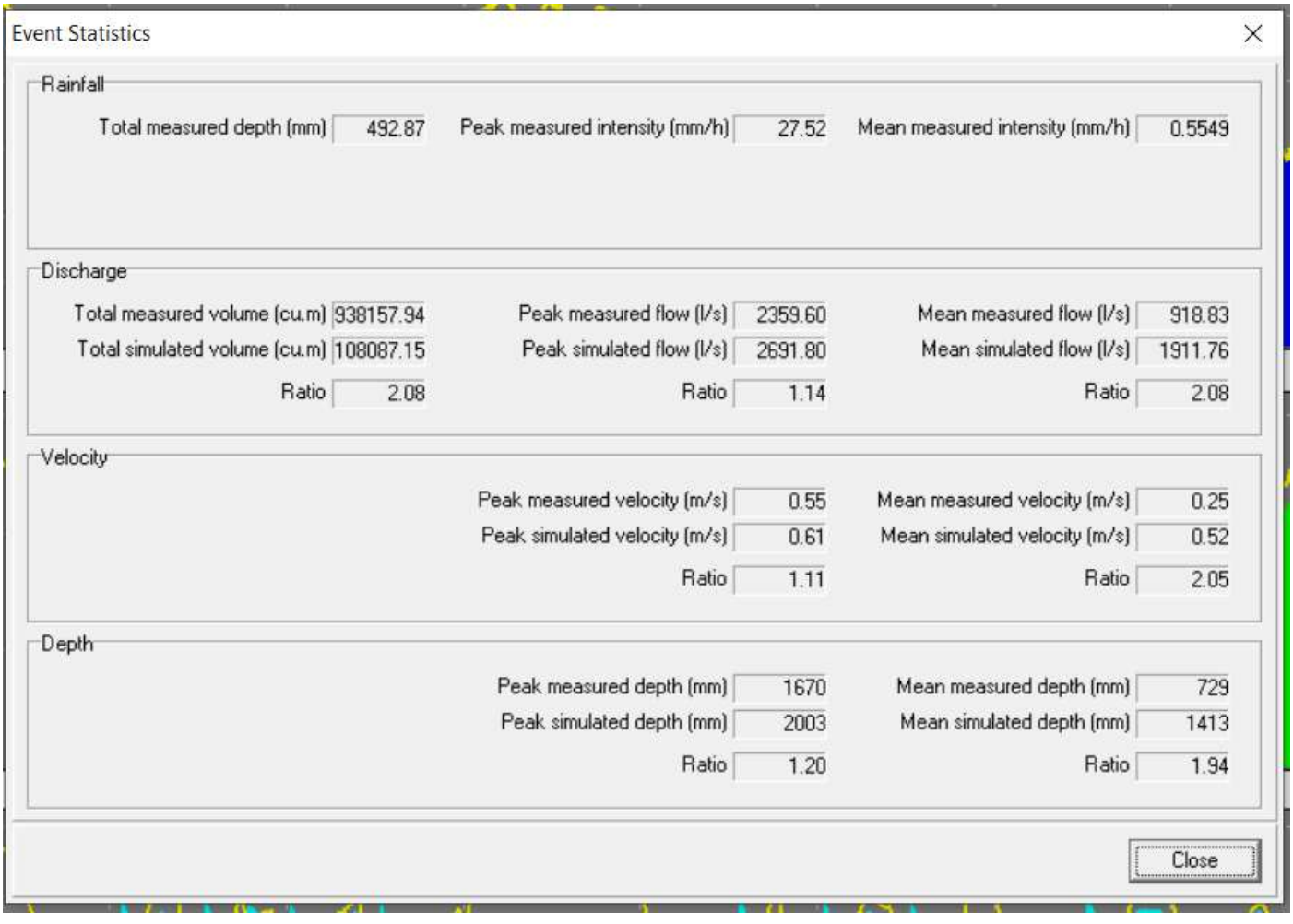
802001 WW3


Gauges
Events
Hydrographs
Scattergraphs
Statistics
Log
Event
WW1
WW2
WW3
SWG
Flow Gauge
802065
802310
802001
802051N
Rain Gauge
802049R
802051R
802053R
802303R
Build
Statistics
Options
Print
Print All
Zoom
Zoom Extents
Close
Rainfall (mm/h)
Discharge (l/s)
Velocity (m/s)
Depth (mm)
Date
24/01/2025
16/03/2025
Measured
Simulated


Event Statistics
Rainfall
Total measured depth (mm) 121.82
Peak measured intensity (mm/h) 40.64
Mean measured intensity (mm/h) 0.0995
Discharge
Total measured volume (cu.m) 670663.12
Peak measured flow (l/s) 3411.36
Mean measured flow (l/s) 1740.44
Total simulated volume (cu.m) 125616.70
Peak simulated flow (l/s) 3281.80
Mean simulated flow (l/s) 1844.80
Ratio 1.06
Ratio 0.96
Ratio 1.06
Velocity
Peak measured velocity (m/s) 0.78
Mean measured velocity (m/s) 0.57
Peak simulated velocity (m/s) 0.71
Mean simulated velocity (m/s) 0.60
Ratio 0.91
Ratio 1.06
Depth
Peak measured depth (mm) 1805
Mean measured depth (mm) 1236
Peak simulated depth (mm) 1716
Mean simulated depth (mm) 1143
Ratio 0.95
Ratio 0.92
Close

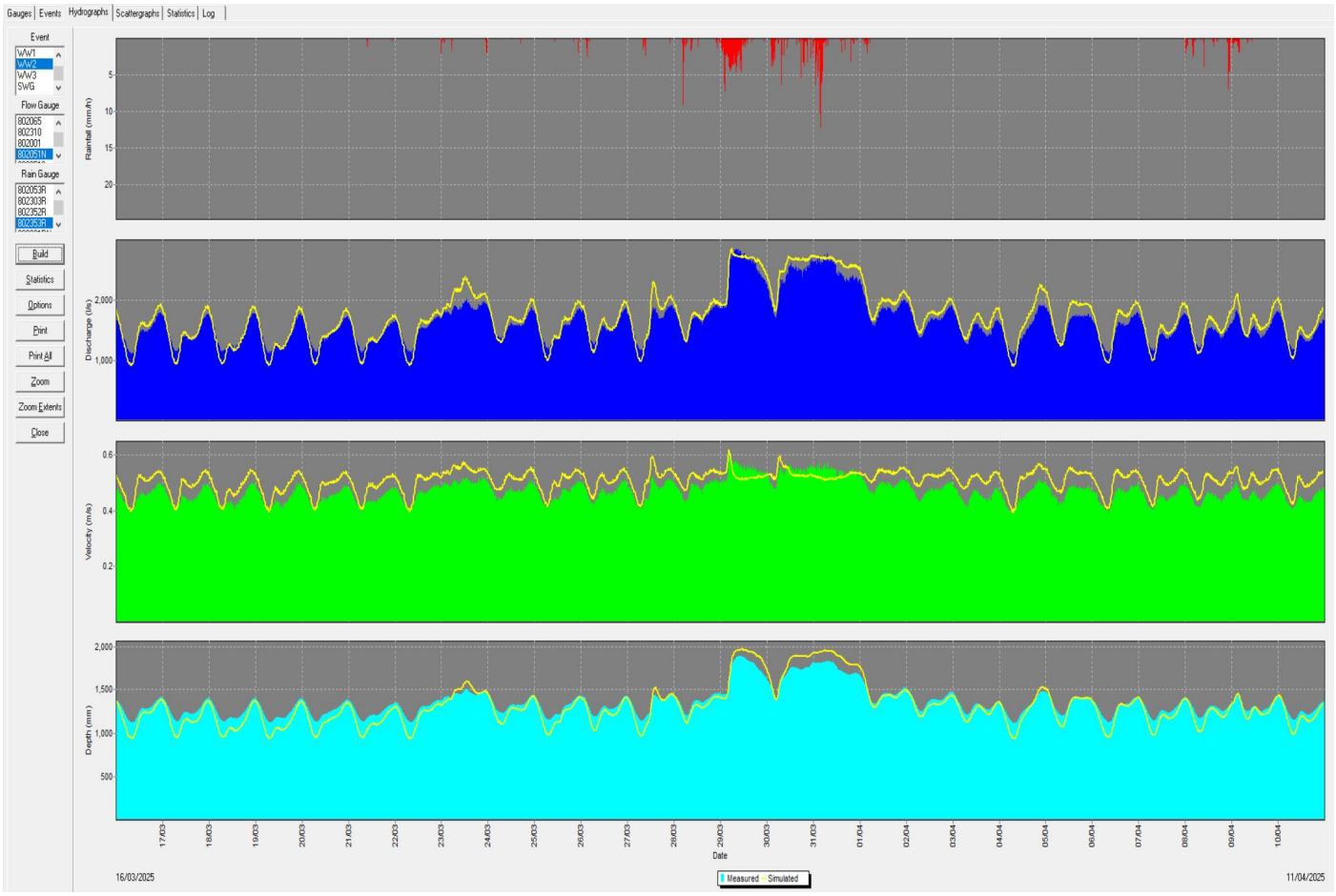
802051N WW1

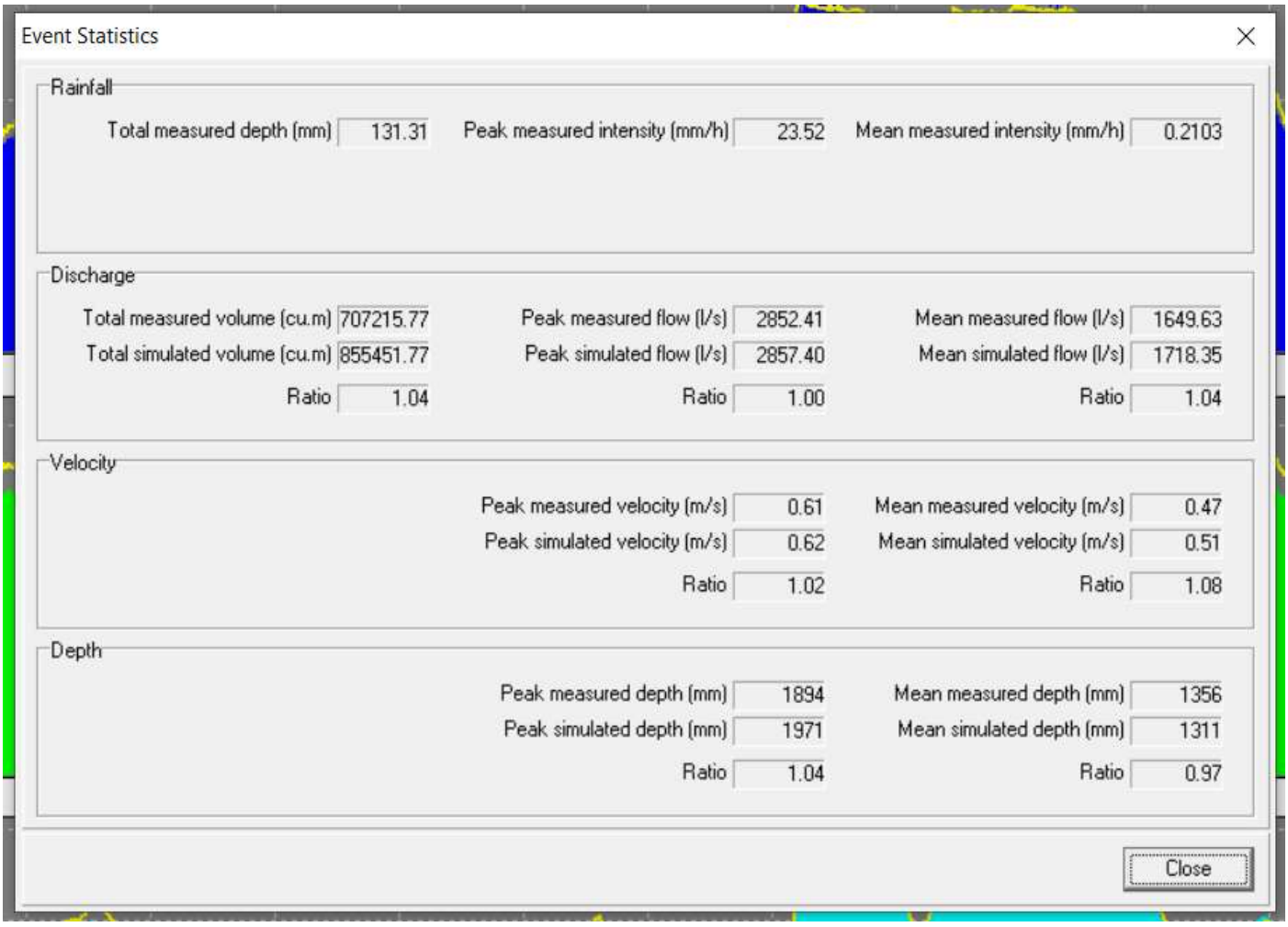




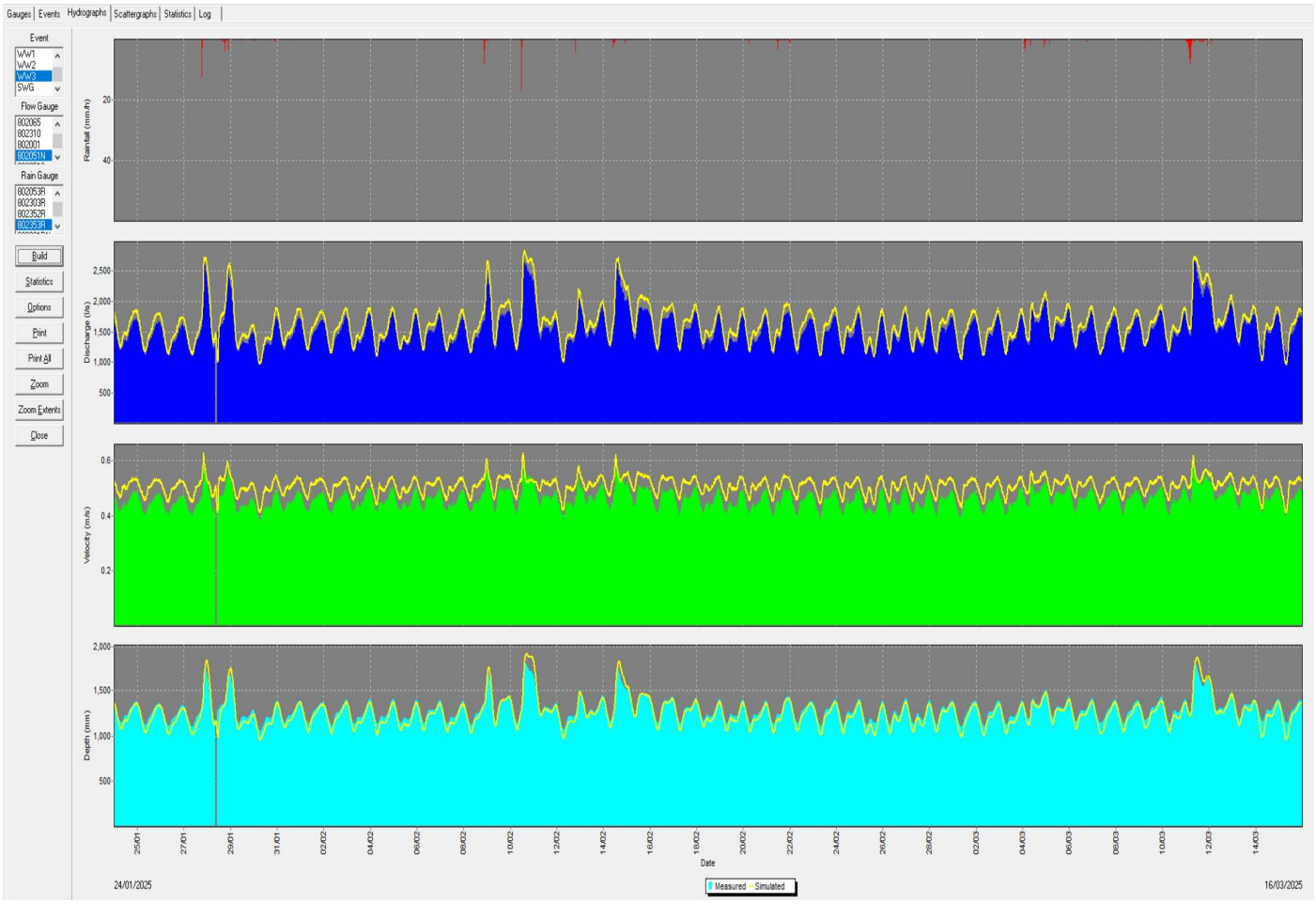
Due to Missing Gauge Data, the Statistics Average couldn’t be evaluated.

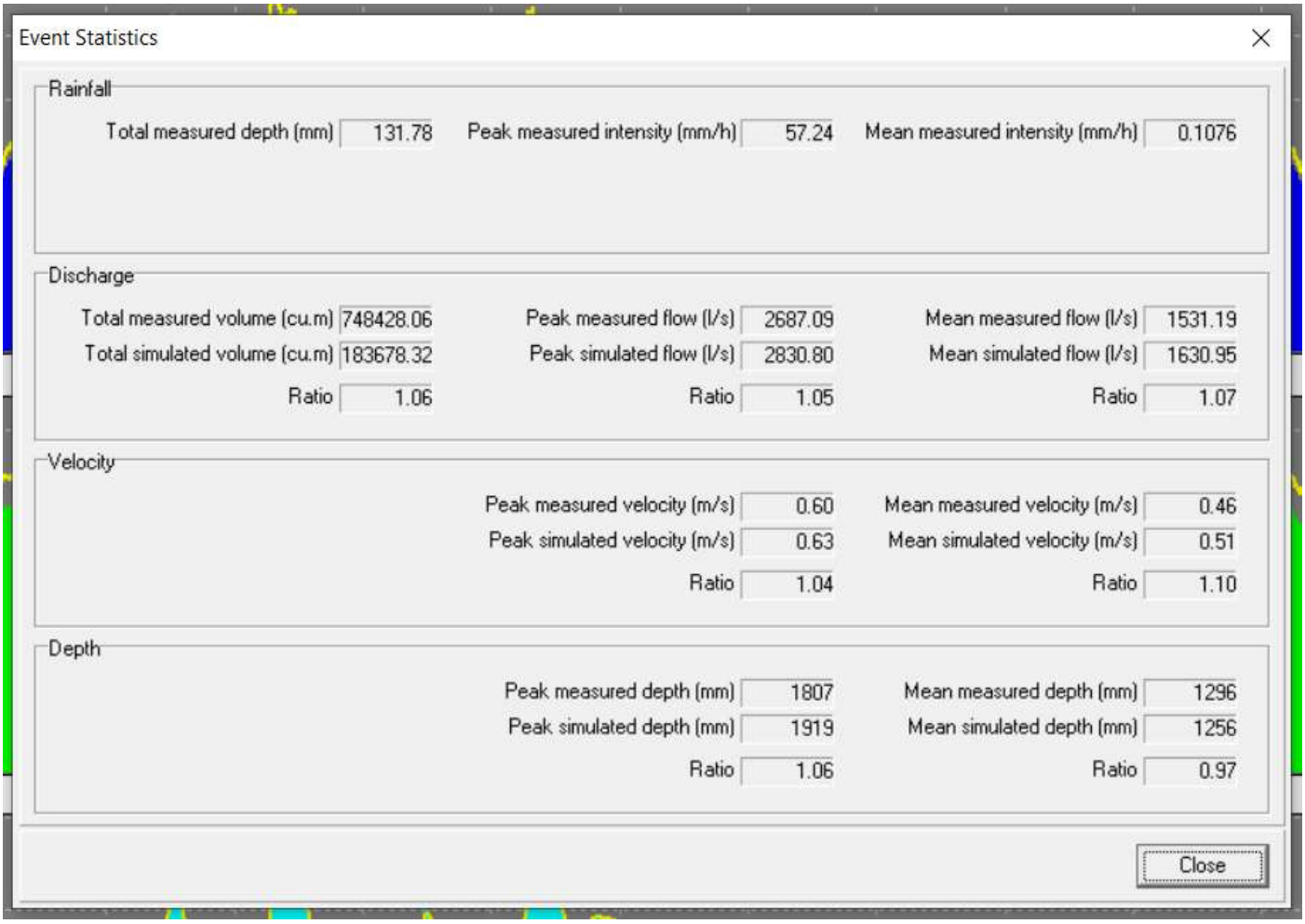
802051N WW2


Gauges | Events | Hydrographs | Scattergraphs | Statistics | Log
Event
WW1
WW2
WW3
SWG
Flow Gauge
802065
802310
802001
802051N
Rain Gauge
802053R
802303R
802352R
802353R
Build
Statistics
Options
Print
Print All
Zoom
Zoom Extents
Close
Rainfall (mm/h)
Discharge (l/s)
Velocity (m/s)
Depth (mm)
Date
16/03/2025
11/04/2025
Measured
Simulated

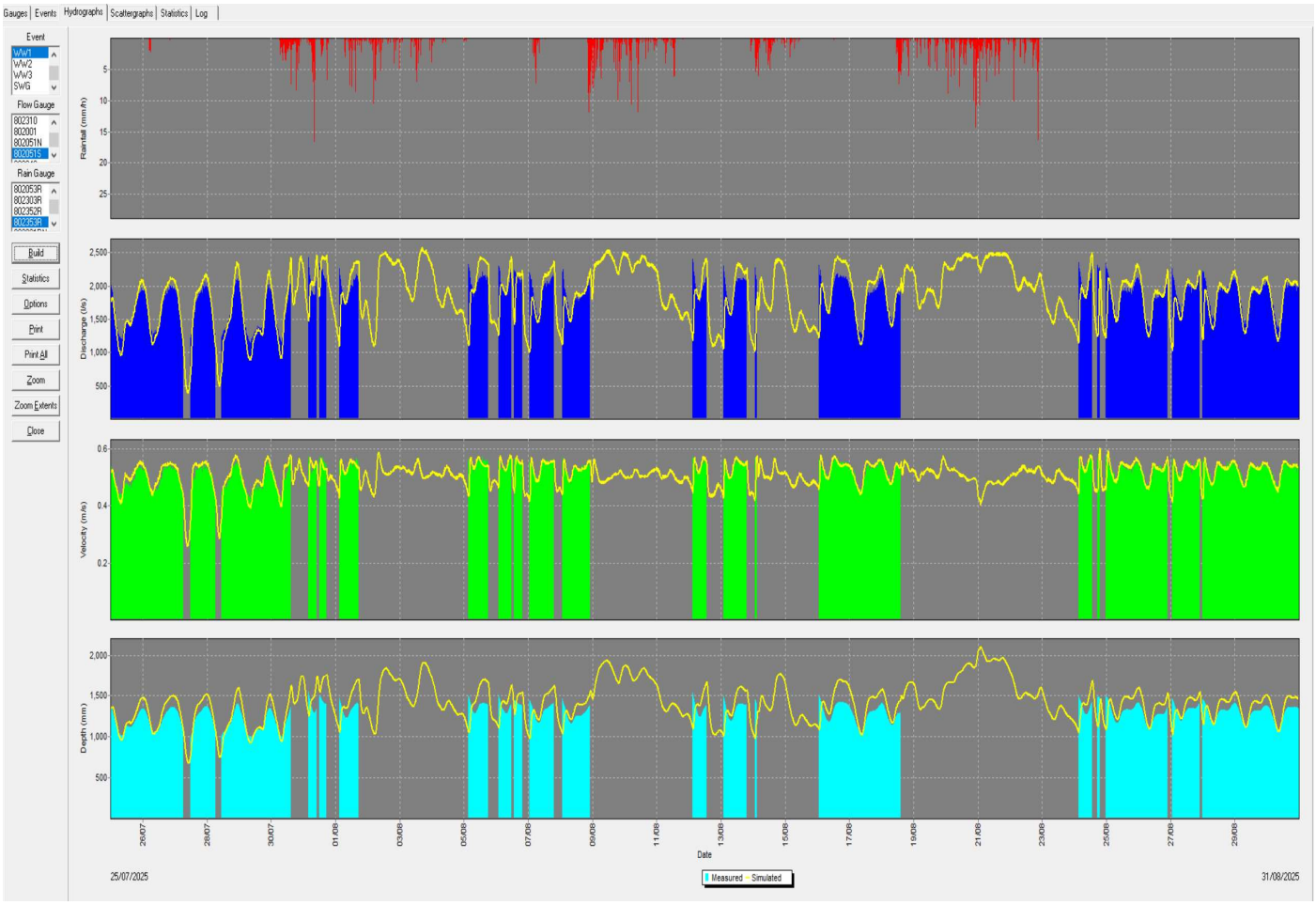

Event Statistics
Rainfall
Total measured depth (mm) 131.31
Peak measured intensity (mm/h) 23.52
Mean measured intensity (mm/h) 0.2103
Discharge
Total measured volume (cu.m) 707215.77
Total simulated volume (cu.m) 855451.77
Ratio 1.04
Peak measured flow (l/s) 2852.41
Peak simulated flow (l/s) 2857.40
Ratio 1.00
Mean measured flow (l/s) 1649.63
Mean simulated flow (l/s) 1718.35
Ratio 1.04
Velocity
Peak measured velocity (m/s) 0.61
Peak simulated velocity (m/s) 0.62
Ratio 1.02
Mean measured velocity (m/s) 0.47
Mean simulated velocity (m/s) 0.51
Ratio 1.08
Depth
Peak measured depth (mm) 1894
Peak simulated depth (mm) 1971
Ratio 1.04
Mean measured depth (mm) 1356
Mean simulated depth (mm) 1311
Ratio 0.97
Close

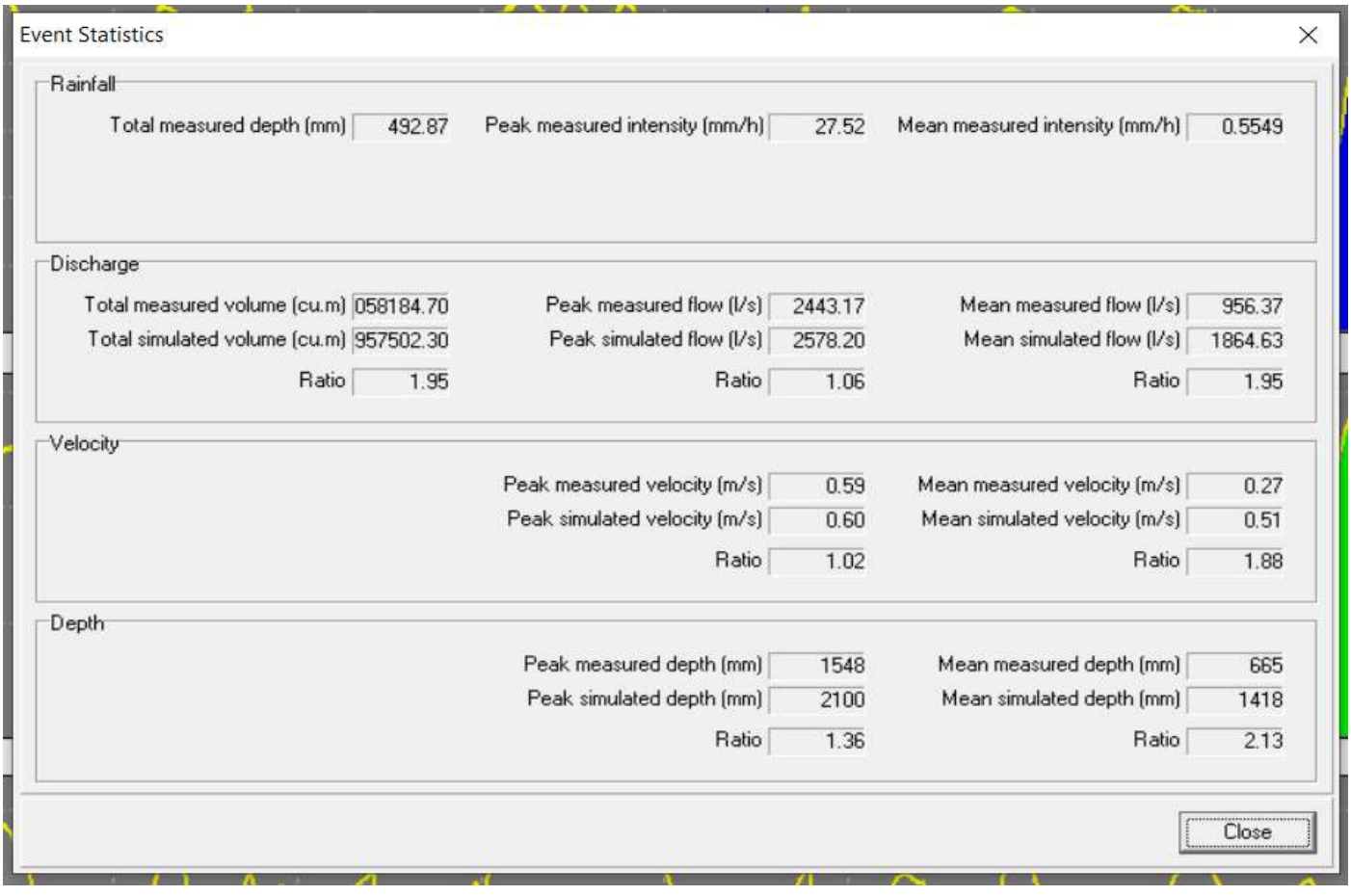
802051N WW3


Gauges | Events | Hydrographs | Scattergraphs | Statistics | Log
Event
WW1
WW2
WW3
SWG
Flow Gauge
802065
802310
802001
802051N
Rain Gauge
802053R
802303R
802352R
802353R
Build
Statistics
Options
Print
Print All
Zoom
Zoom Extents
Close
Rainfall (mm/h)
Discharge (l/s)
Velocity (m/s)
Depth (mm)
Date
24/01/2025
Measured
Simulated
16/03/2025


Event Statistics
Rainfall
Total measured depth (mm) 131.78
Peak measured intensity (mm/h) 57.24
Mean measured intensity (mm/h) 0.1076
Discharge
Total measured volume (cu.m) 748428.06
Peak measured flow (l/s) 2687.09
Mean measured flow (l/s) 1531.19
Total simulated volume (cu.m) 183678.32
Peak simulated flow (l/s) 2830.80
Mean simulated flow (l/s) 1630.95
Ratio 1.06
Ratio 1.05
Ratio 1.07
Velocity
Peak measured velocity (m/s) 0.60
Mean measured velocity (m/s) 0.46
Peak simulated velocity (m/s) 0.63
Mean simulated velocity (m/s) 0.51
Ratio 1.04
Ratio 1.10
Depth
Peak measured depth (mm) 1807
Mean measured depth (mm) 1296
Peak simulated depth (mm) 1919
Mean simulated depth (mm) 1256
Ratio 1.06
Ratio 0.97
Close

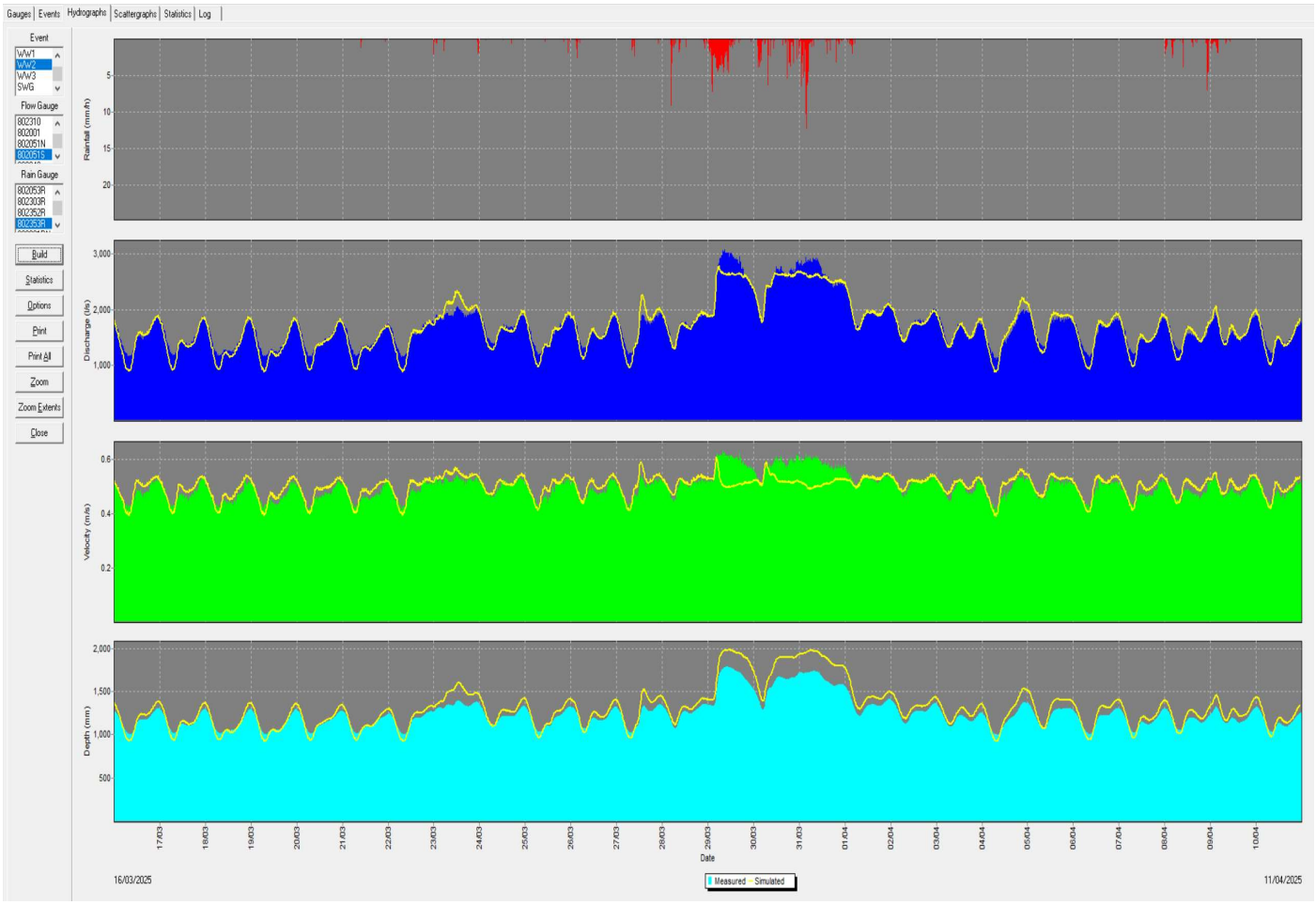
802051S WW1

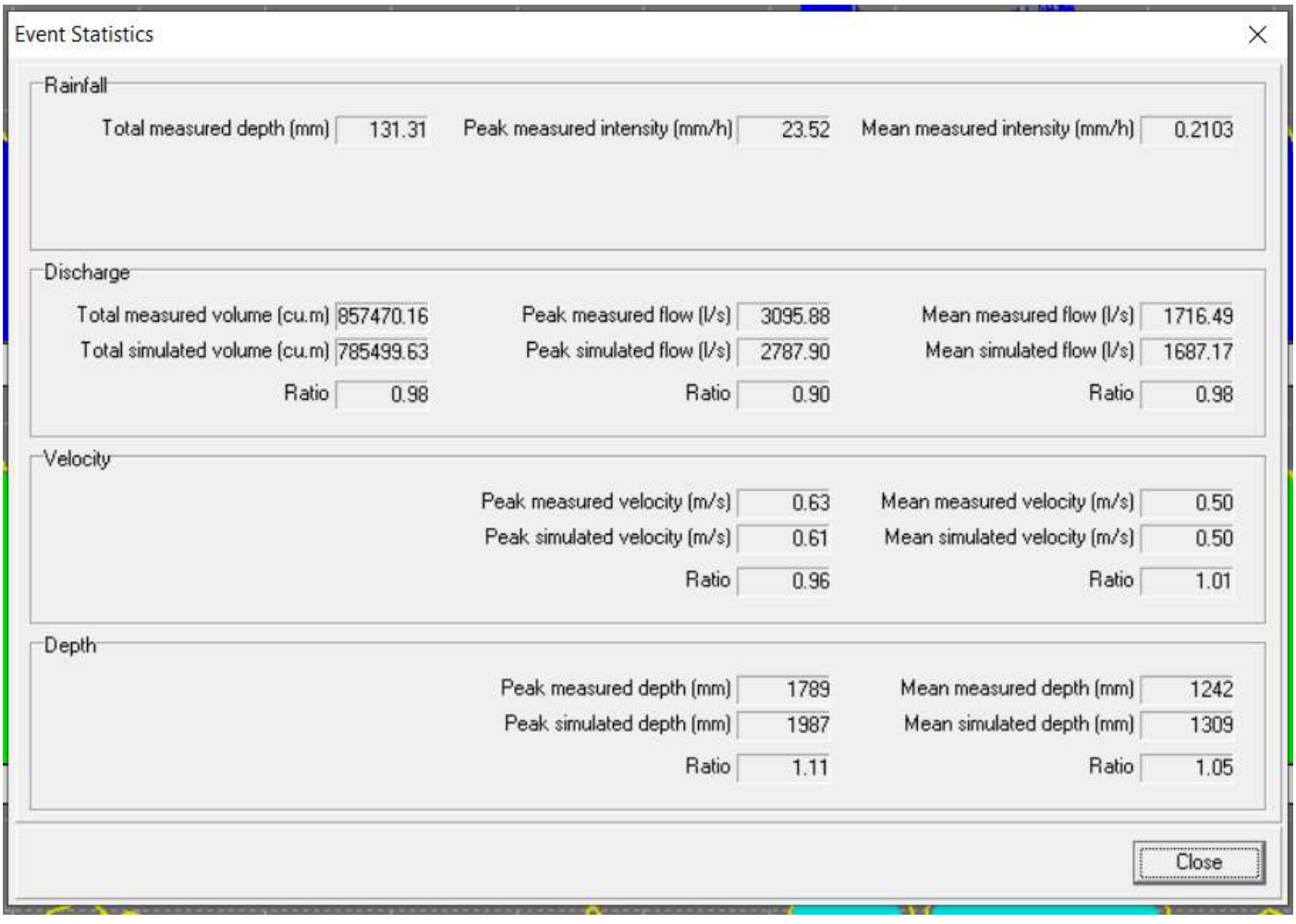




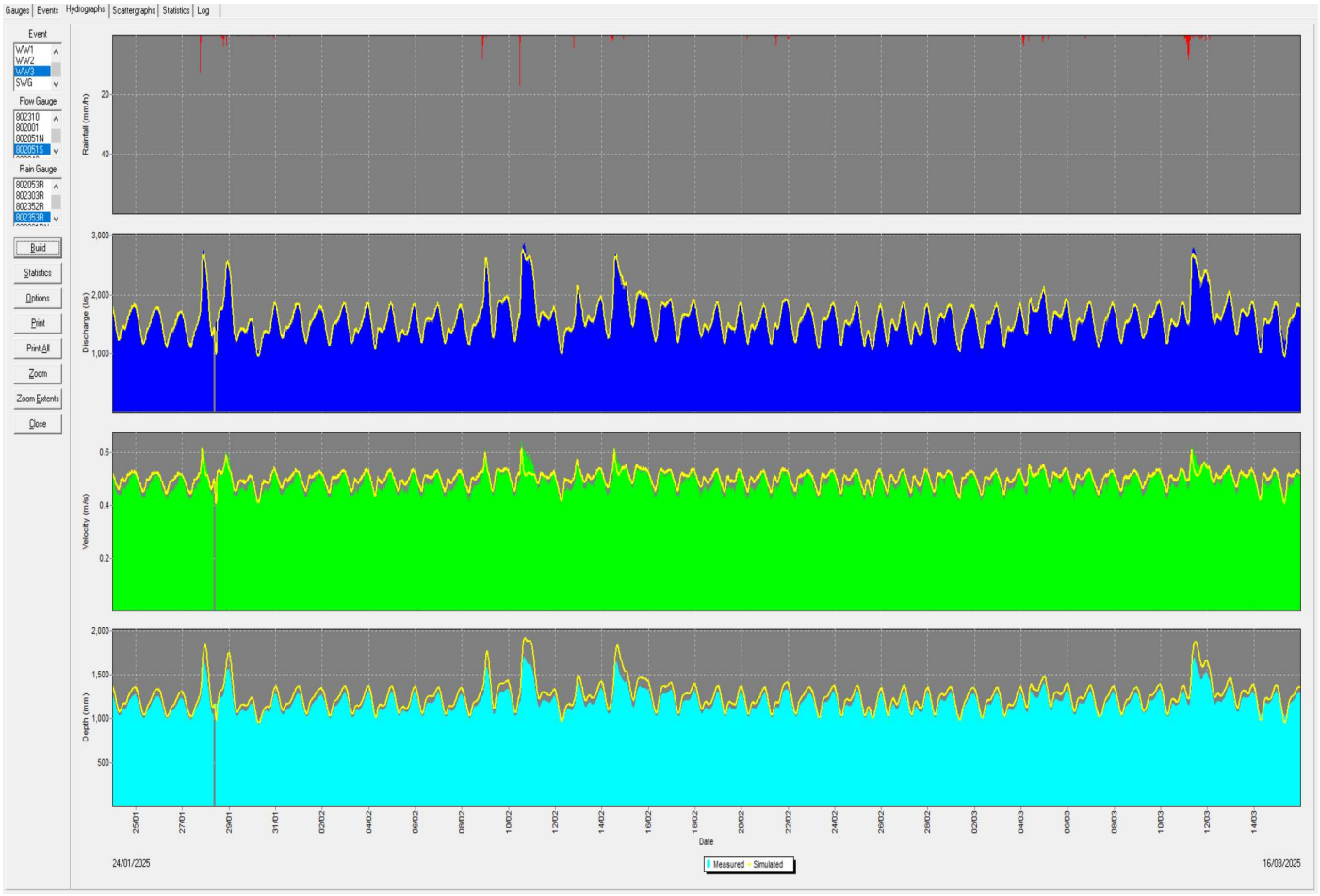
Due to Missing Gauge Data, the Statistics Average couldn’t be evaluated.

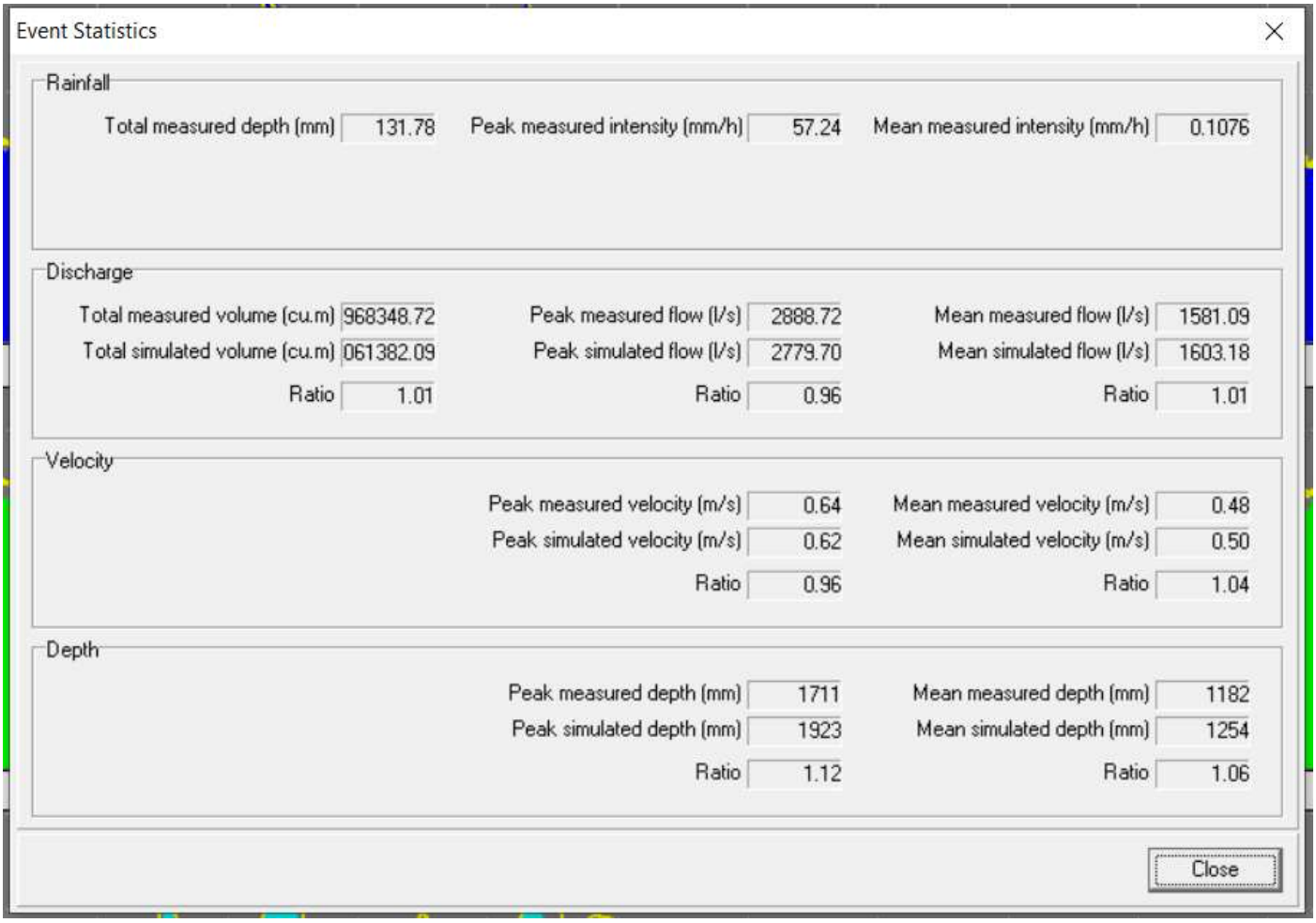
802051S WW2


Gauges | Events | Hydrographs | Scattergraphs | Statistics | Log
Event
WW1
WW2
WW3
SWG
Flow Gauge
802310
802001
802051N
802051S
Rain Gauge
802053R
802303R
802352R
802353R
Build
Statistics
Options
Print
Print All
Zoom
Zoom Extents
Close
Rainfall (mm/h)
Discharge (l/s)
Velocity (m/s)
Depth (mm)
Date
16/03/2025
11/04/2025
Measured
Simulated

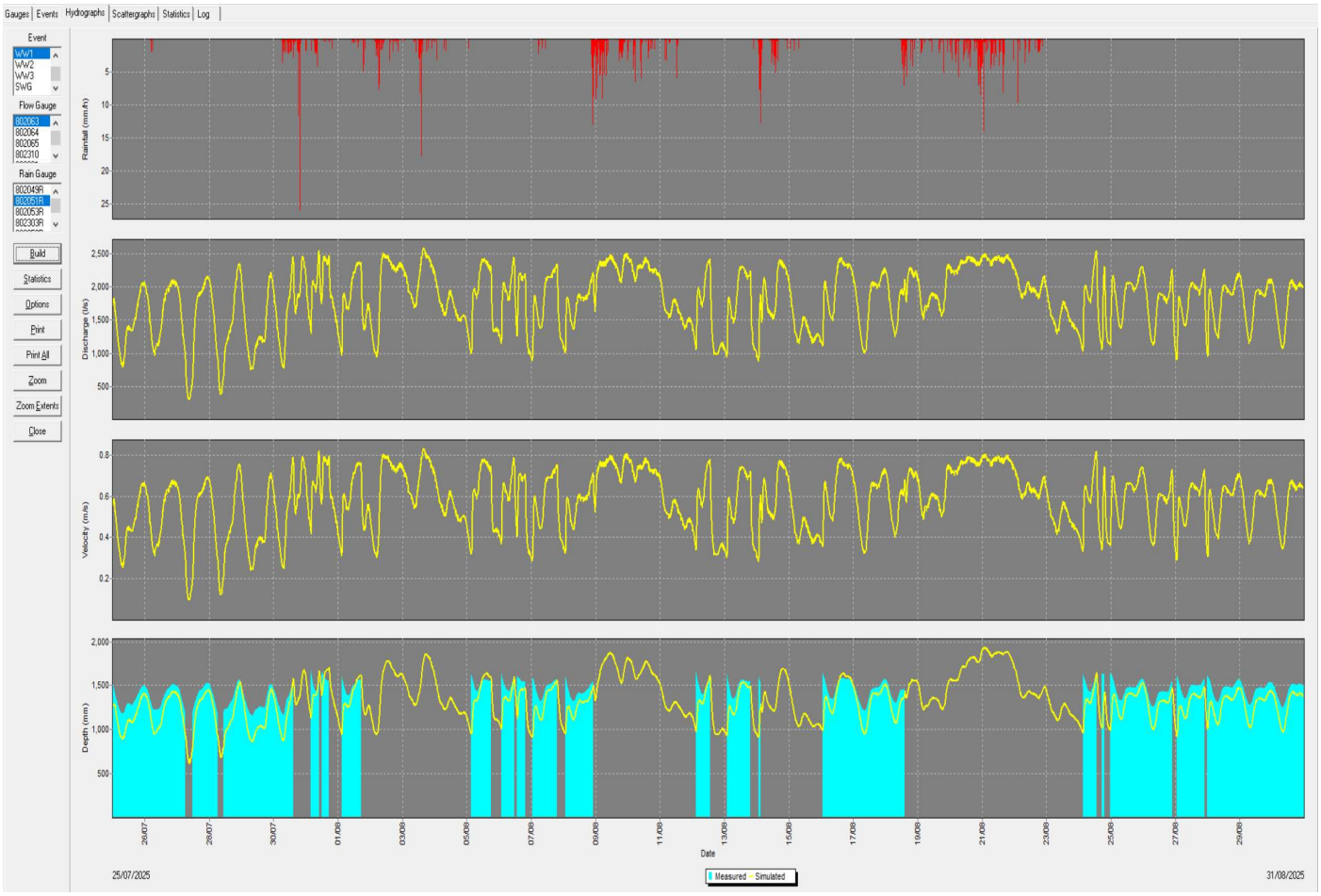

Event Statistics
Rainfall
Total measured depth (mm) 131.31
Peak measured intensity (mm/h) 23.52
Mean measured intensity (mm/h) 0.2103
Discharge
Total measured volume (cu.m) 857470.16
Peak measured flow (l/s) 3095.88
Mean measured flow (l/s) 1716.49
Total simulated volume (cu.m) 785499.63
Peak simulated flow (l/s) 2787.90
Mean simulated flow (l/s) 1687.17
Ratio 0.98
Ratio 0.90
Ratio 0.98
Velocity
Peak measured velocity (m/s) 0.63
Mean measured velocity (m/s) 0.50
Peak simulated velocity (m/s) 0.61
Mean simulated velocity (m/s) 0.50
Ratio 0.96
Ratio 1.01
Depth
Peak measured depth (mm) 1789
Mean measured depth (mm) 1242
Peak simulated depth (mm) 1987
Mean simulated depth (mm) 1309
Ratio 1.11
Ratio 1.05
Close

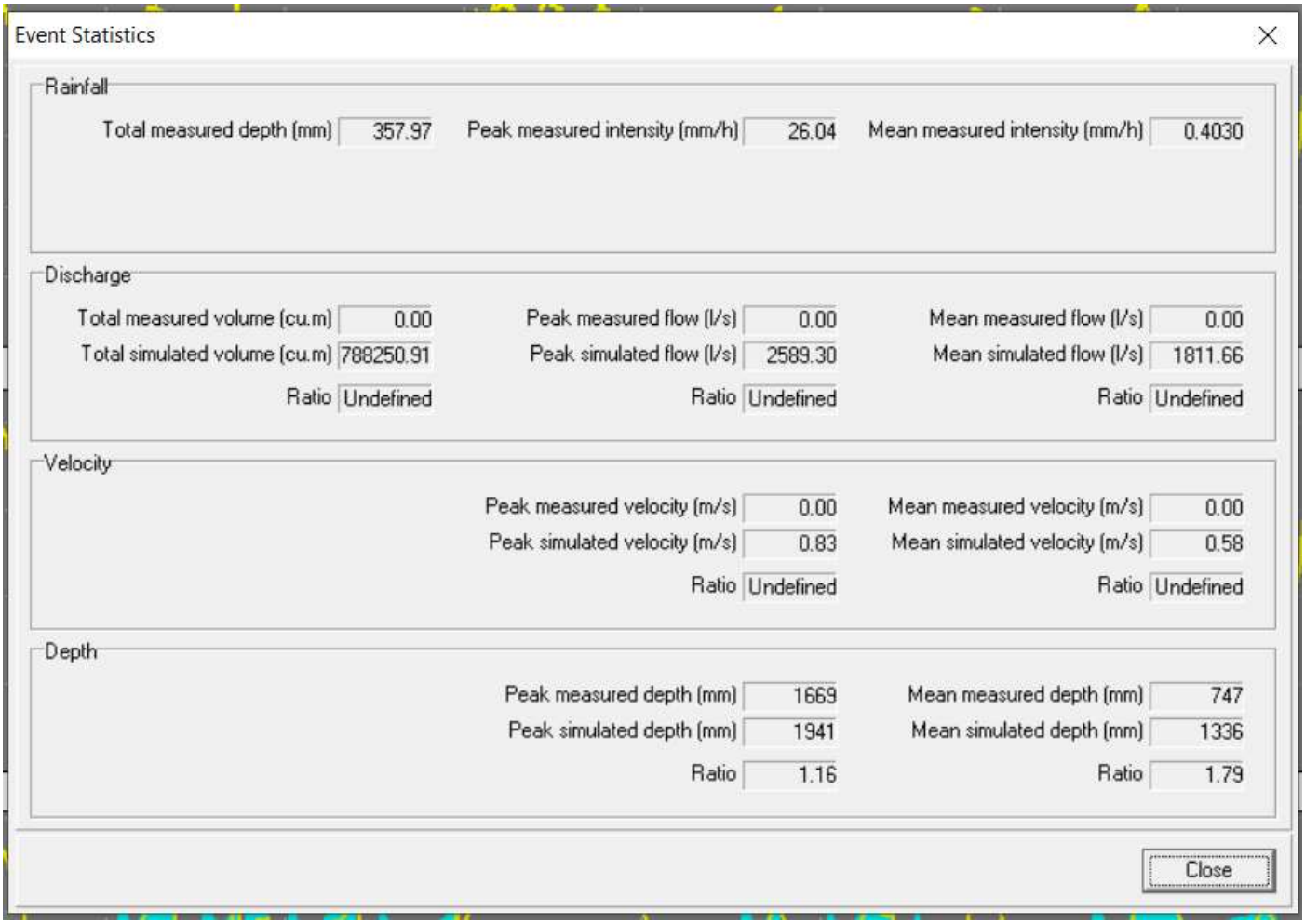
802051S WW3


Gauges | Events | Hydrographs | Scattergraphs | Statistics | Log
Event
WW1
WW2
WW3
SW6
Flow Gauge
802310
802001
802051N
802051S
Rain Gauge
802053R
802303R
802352R
802353R
Build
Statistics
Options
Print
Print All
Zoom
Zoom Extents
Close
Rainfall (mm/h)
Discharge (l/s)
Velocity (m/s)
Depth (mm)
Date
24/01/2025
16/03/2025
Measured
Simulated

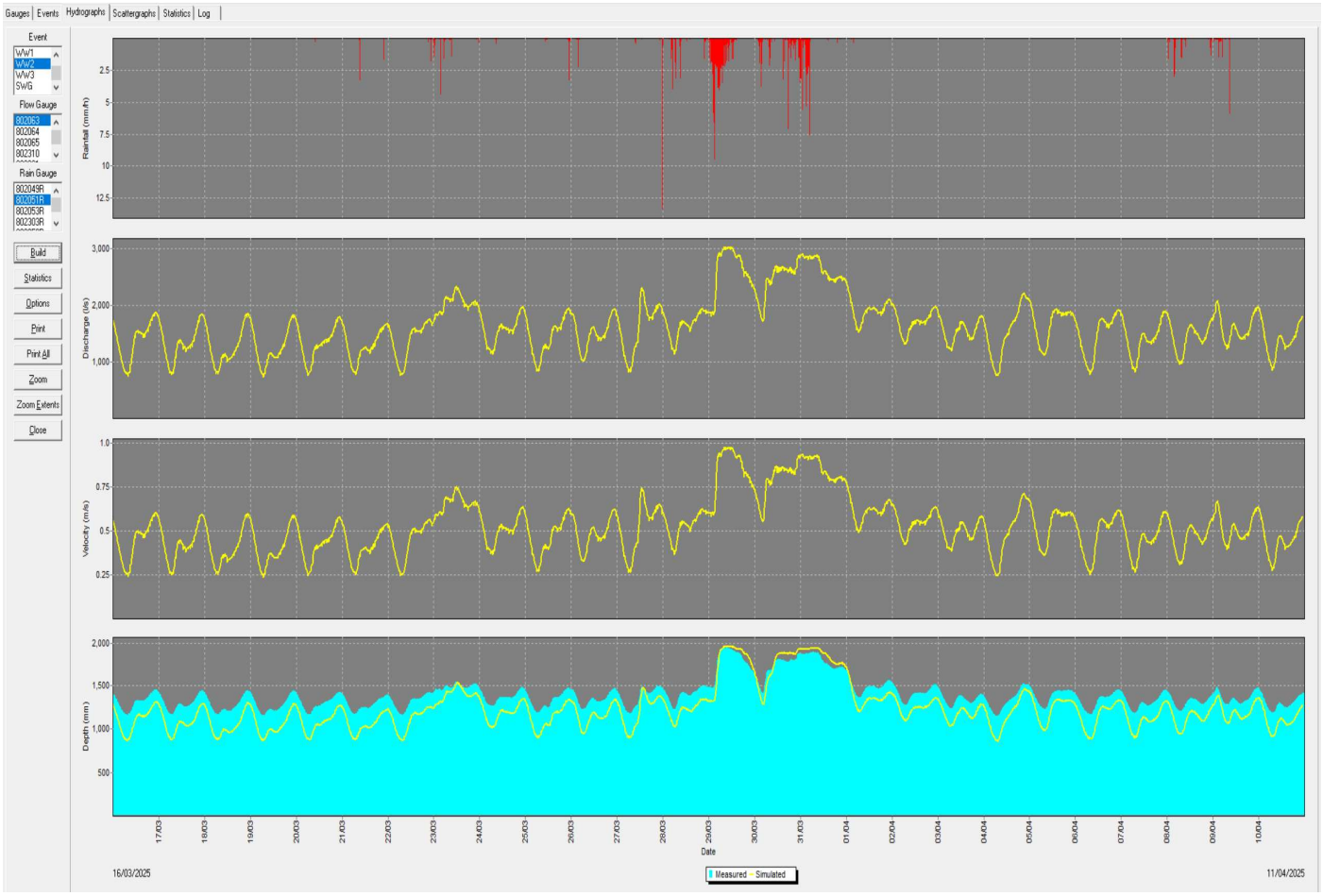

Event Statistics
Rainfall
Total measured depth (mm) 131.78
Peak measured intensity (mm/h) 57.24
Mean measured intensity (mm/h) 0.1076
Discharge
Total measured volume (cu.m) 968348.72
Total simulated volume (cu.m) 061382.09
Ratio 1.01
Peak measured flow (l/s) 2888.72
Peak simulated flow (l/s) 2779.70
Ratio 0.96
Mean measured flow (l/s) 1581.09
Mean simulated flow (l/s) 1603.18
Ratio 1.01
Velocity
Peak measured velocity (m/s) 0.64
Peak simulated velocity (m/s) 0.62
Ratio 0.96
Mean measured velocity (m/s) 0.48
Mean simulated velocity (m/s) 0.50
Ratio 1.04
Depth
Peak measured depth (mm) 1711
Peak simulated depth (mm) 1923
Ratio 1.12
Mean measured depth (mm) 1182
Mean simulated depth (mm) 1254
Ratio 1.06
Close

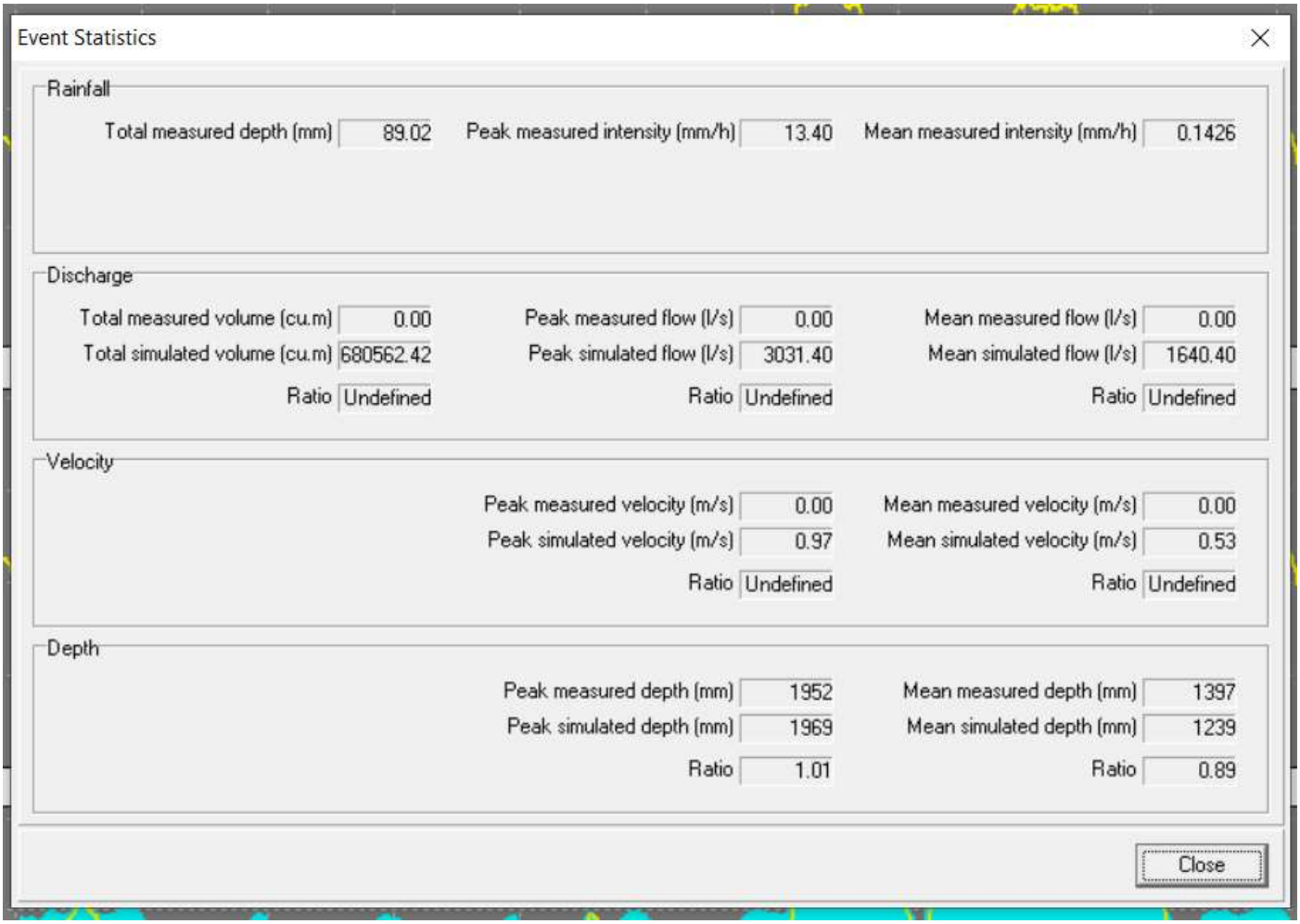
802063 WW1


Gauges | Events | Hydrographs | Scattergraphs | Statistics | Log
Event
WW1
WW2
WW3
SWG
Flow Gauge
802063
802064
802065
802310
Rain Gauge
802049R
802051R
802053R
802303R
Build
Statistics
Options
Print
Print All
Zoom
Zoom Extents
Close
Rainfall (mm/h)
Discharge (l/s)
Velocity (m/s)
Depth (mm)
Date
25/07/2025
31/08/2025
Measured
Simulated

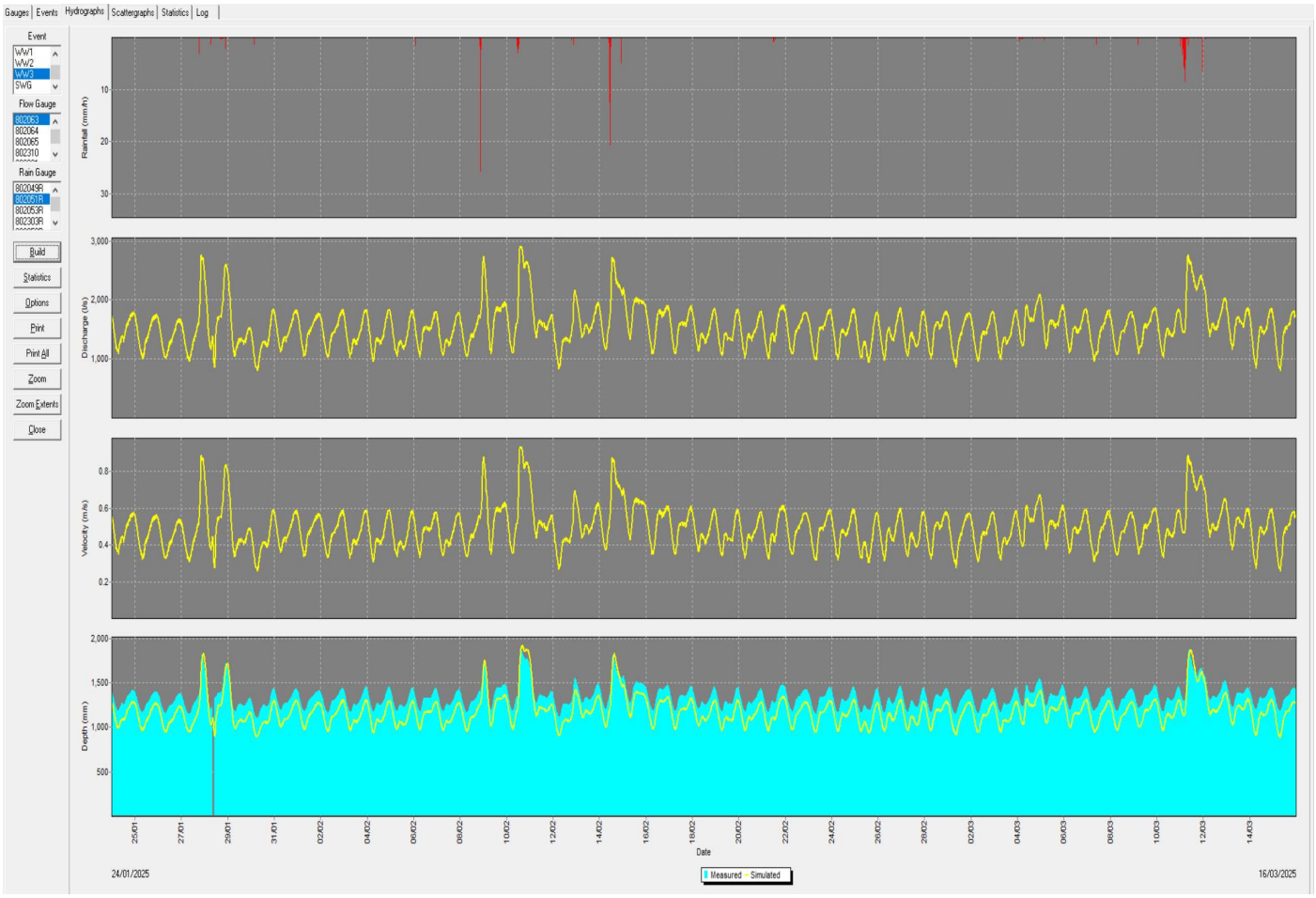

Event Statistics
Rainfall
Total measured depth (mm) 357.97
Peak measured intensity (mm/h) 26.04
Mean measured intensity (mm/h) 0.4030
Discharge
Total measured volume (cu.m) 0.00
Peak measured flow (l/s) 0.00
Mean measured flow (l/s) 0.00
Total simulated volume (cu.m) 788250.91
Peak simulated flow (l/s) 2589.30
Mean simulated flow (l/s) 1811.66
Ratio Undefined
Ratio Undefined
Ratio Undefined
Velocity
Peak measured velocity (m/s) 0.00
Mean measured velocity (m/s) 0.00
Peak simulated velocity (m/s) 0.83
Mean simulated velocity (m/s) 0.58
Ratio Undefined
Ratio Undefined
Depth
Peak measured depth (mm) 1669
Mean measured depth (mm) 747
Peak simulated depth (mm) 1941
Mean simulated depth (mm) 1336
Ratio 1.16
Ratio 1.79
Close

802063 WW2


Gauges | Events | Hydrographs | Scattergraphs | Statistics | Log
Event
WW1
WW2
WW3
SWG
Flow Gauge
802063
802064
802065
802310
Rain Gauge
802049R
802061R
802053R
802303R
Build
Statistics
Options
Print
Print All
Zoom
Zoom Extents
Close
Rainfall (mm/h)
Discharge (l/s)
Velocity (m/s)
Depth (mm)
Date
16/03/2025
11/04/2025
Measured
Simulated

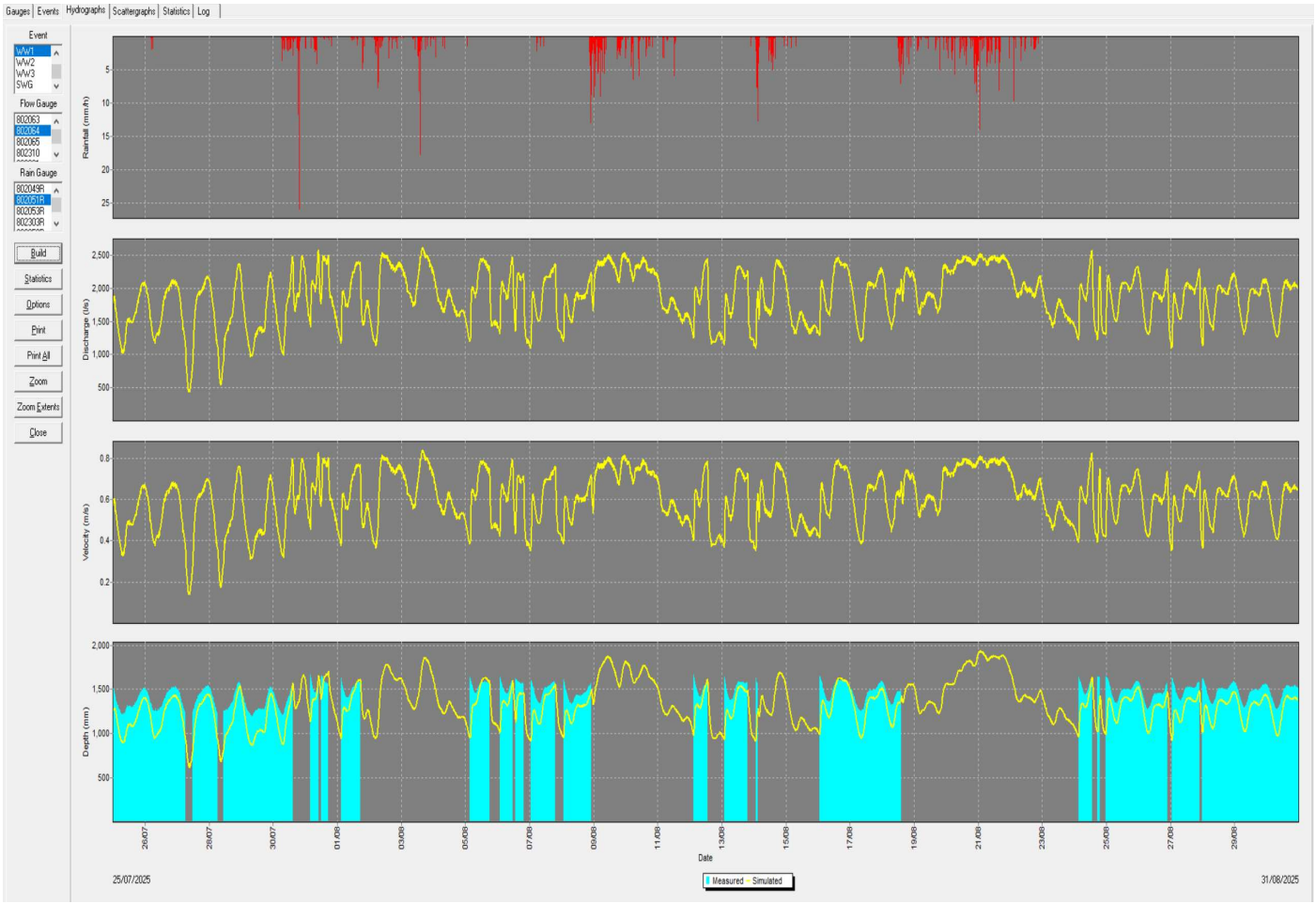

Event Statistics
Rainfall
Total measured depth (mm) 89.02
Peak measured intensity (mm/h) 13.40
Mean measured intensity (mm/h) 0.1426
Discharge
Total measured volume (cu.m) 0.00
Peak measured flow (l/s) 0.00
Mean measured flow (l/s) 0.00
Total simulated volume (cu.m) 680562.42
Peak simulated flow (l/s) 3031.40
Mean simulated flow (l/s) 1640.40
Ratio Undefined
Ratio Undefined
Ratio Undefined
Velocity
Peak measured velocity (m/s) 0.00
Mean measured velocity (m/s) 0.00
Peak simulated velocity (m/s) 0.97
Mean simulated velocity (m/s) 0.53
Ratio Undefined
Ratio Undefined
Depth
Peak measured depth (mm) 1952
Mean measured depth (mm) 1397
Peak simulated depth (mm) 1969
Mean simulated depth (mm) 1239
Ratio 1.01
Ratio 0.89
Close

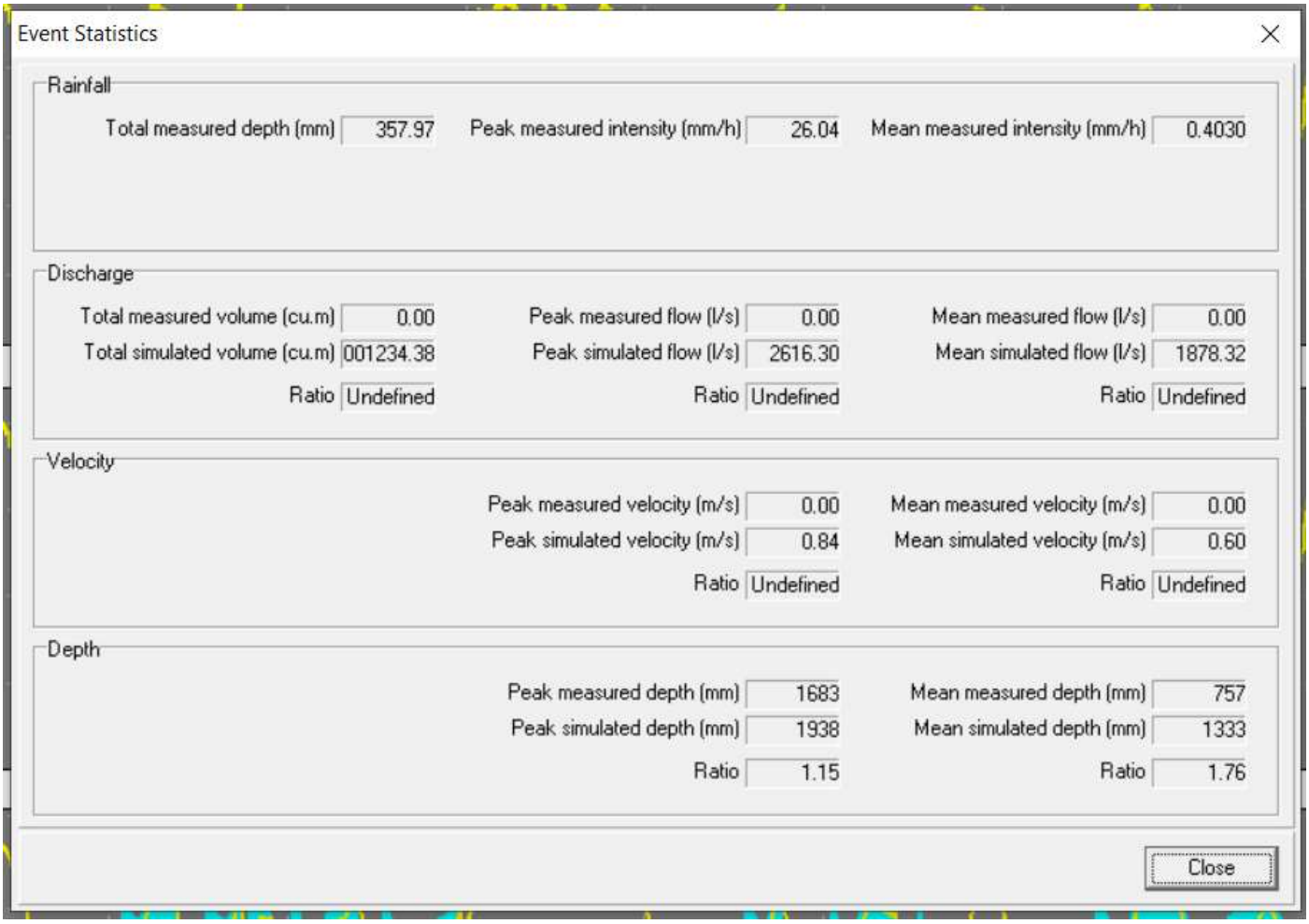
802603 WW3


Gauges | Events | Hydrographs | Scattergraphs | Statistics | Log
Event
WW1
WW2
WW3
SWG
Flow Gauge
802063
802064
802065
802310
Rain Gauge
802049R
802051R
802053R
802303R
Build
Statistics
Options
Print
Print All
Zoom
Zoom Extents
Close
Rainfall (mm/h)
Discharge (l/s)
Velocity (m/s)
Depth (mm)
Date
24/01/2025
16/03/2025
Measured
Simulated

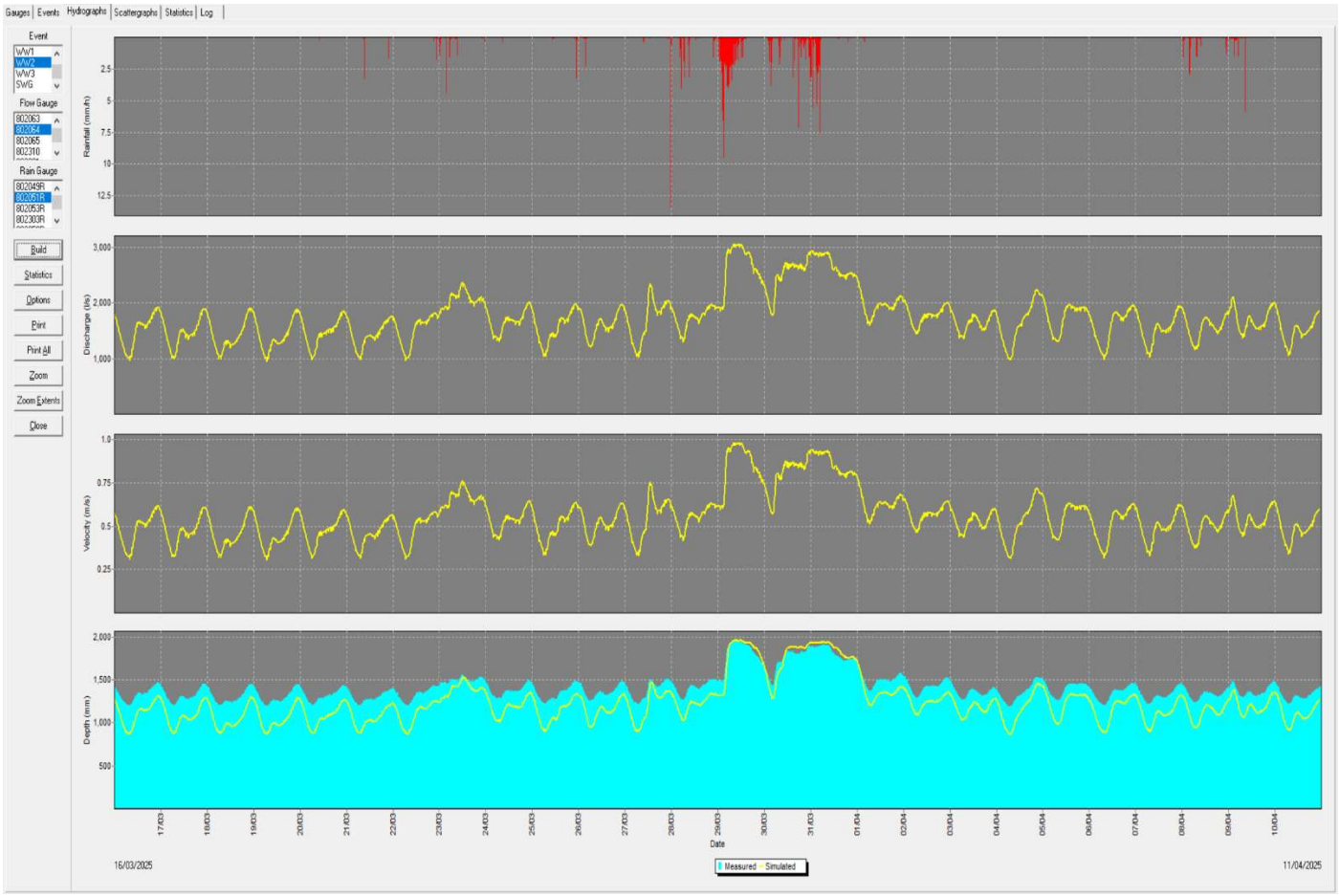

Event Statistics
Rainfall
Total measured depth (mm) 105.46
Peak measured intensity (mm/h) 32.88
Mean measured intensity (mm/h) 0.0861
Discharge
Total measured volume (cu.m) 0.00
Total simulated volume (cu.m) 786565.56
Ratio Undefined
Peak measured flow (l/s) 0.00
Peak simulated flow (l/s) 2907.40
Ratio Undefined
Mean measured flow (l/s) 0.00
Mean simulated flow (l/s) 1540.79
Ratio Undefined
Velocity
Peak measured velocity (m/s) 0.00
Peak simulated velocity (m/s) 0.93
Ratio Undefined
Mean measured velocity (m/s) 0.00
Mean simulated velocity (m/s) 0.50
Ratio Undefined
Depth
Peak measured depth (mm) 1879
Peak simulated depth (mm) 1926
Ratio 1.03
Mean measured depth (mm) 1338
Mean simulated depth (mm) 1179
Ratio 0.88
Close

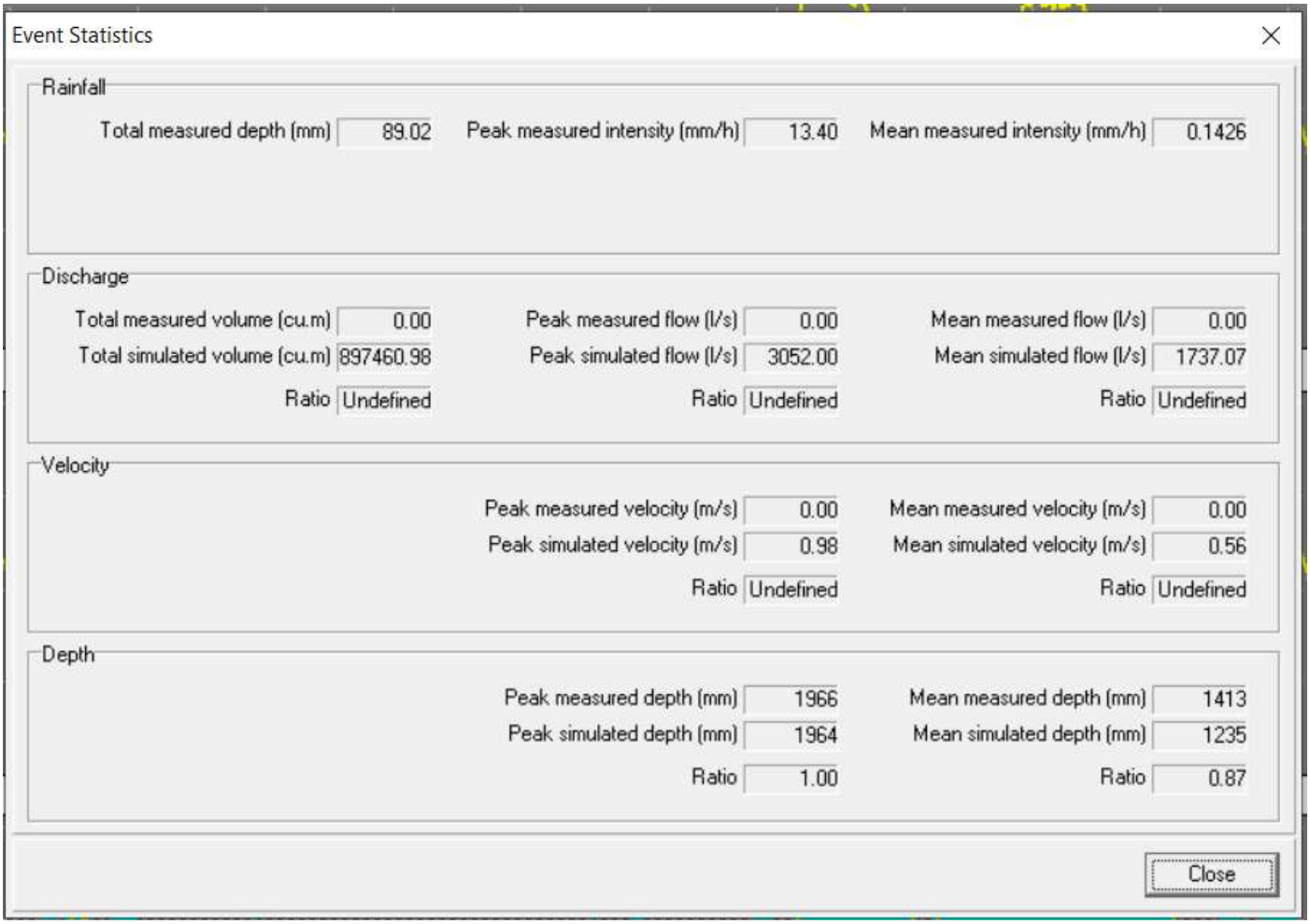
802064 WW1


Gauges | Events | Hydrographs | Scattergraphs | Statistics | Log
Event
WW1
WW2
WW3
SWG
Flow Gauge
802063
802064
802065
802310
Rain Gauge
802049R
802051R
802053R
802309R
Build
Statistics
Options
Print
Print All
Zoom
Zoom Extents
Close
Rainfall (mm/h)
Discharge (l/s)
Velocity (m/s)
Depth (mm)
Date
25/07/2025
31/08/2025
Measured
Simulated

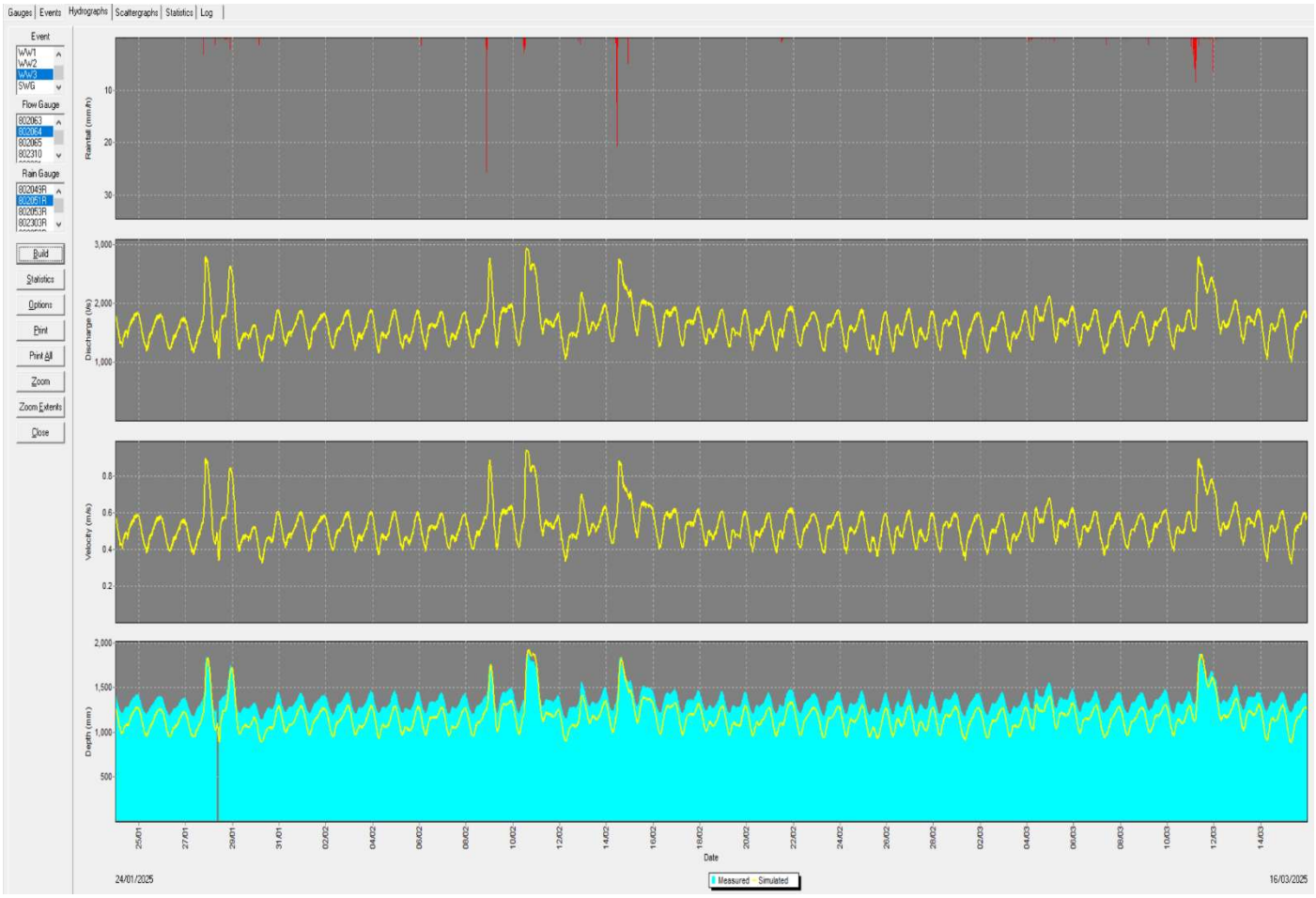

Event Statistics
Rainfall
Total measured depth (mm) 357.97
Peak measured intensity (mm/h) 26.04
Mean measured intensity (mm/h) 0.4030
Discharge
Total measured volume (cu.m) 0.00
Total simulated volume (cu.m) 001234.38
Ratio Undefined
Peak measured flow (l/s) 0.00
Peak simulated flow (l/s) 2616.30
Ratio Undefined
Mean measured flow (l/s) 0.00
Mean simulated flow (l/s) 1878.32
Ratio Undefined
Velocity
Peak measured velocity (m/s) 0.00
Peak simulated velocity (m/s) 0.84
Ratio Undefined
Mean measured velocity (m/s) 0.00
Mean simulated velocity (m/s) 0.60
Ratio Undefined
Depth
Peak measured depth (mm) 1683
Peak simulated depth (mm) 1938
Ratio 1.15
Mean measured depth (mm) 757
Mean simulated depth (mm) 1333
Ratio 1.76
Close

802064 WW2


Gauges | Events | Hydrographs | Scattergraphs | Statistics | Log
Event
WW1
WW2
WW3
SWG
Flow Gauge
802063
802064
802065
802310
Rain Gauge
802049R
802051R
802053R
802303R
Build
Statistics
Options
Print
Print All
Zoom
Zoom Extents
Close
Rainfall (mm/h)
Discharge (l/s)
Velocity (m/s)
Depth (mm)
Date
16/03/2025
Measured
Simulated
11/04/2025

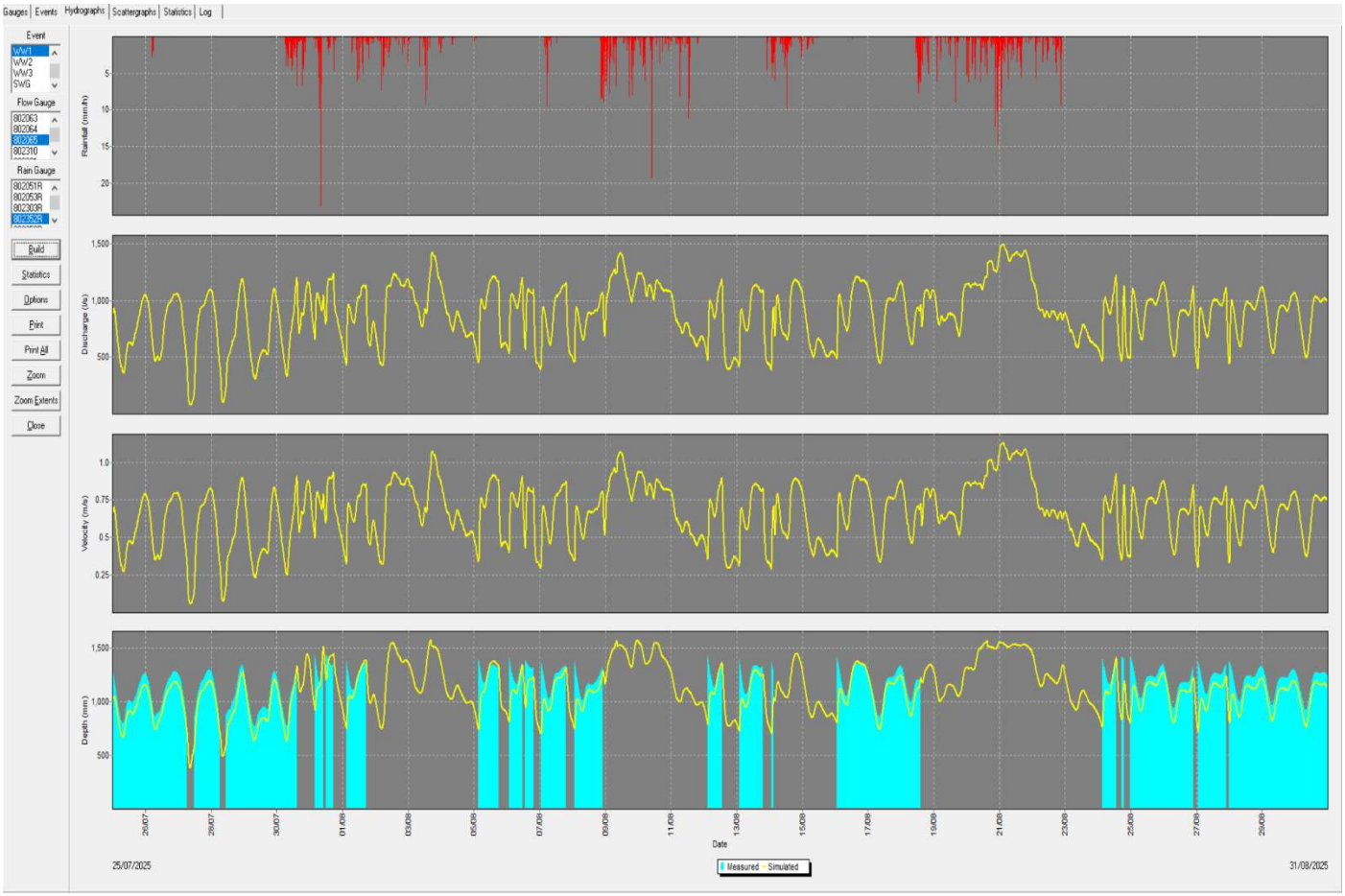

Event Statistics
Rainfall
Total measured depth (mm) 89.02
Peak measured intensity (mm/h) 13.40
Mean measured intensity (mm/h) 0.1426
Discharge
Total measured volume (cu.m) 0.00
Peak measured flow (l/s) 0.00
Mean measured flow (l/s) 0.00
Total simulated volume (cu.m) 897460.98
Peak simulated flow (l/s) 3052.00
Mean simulated flow (l/s) 1737.07
Ratio Undefined
Ratio Undefined
Ratio Undefined
Velocity
Peak measured velocity (m/s) 0.00
Mean measured velocity (m/s) 0.00
Peak simulated velocity (m/s) 0.98
Mean simulated velocity (m/s) 0.56
Ratio Undefined
Ratio Undefined
Depth
Peak measured depth (mm) 1966
Mean measured depth (mm) 1413
Peak simulated depth (mm) 1964
Mean simulated depth (mm) 1235
Ratio 1.00
Ratio 0.87
Close

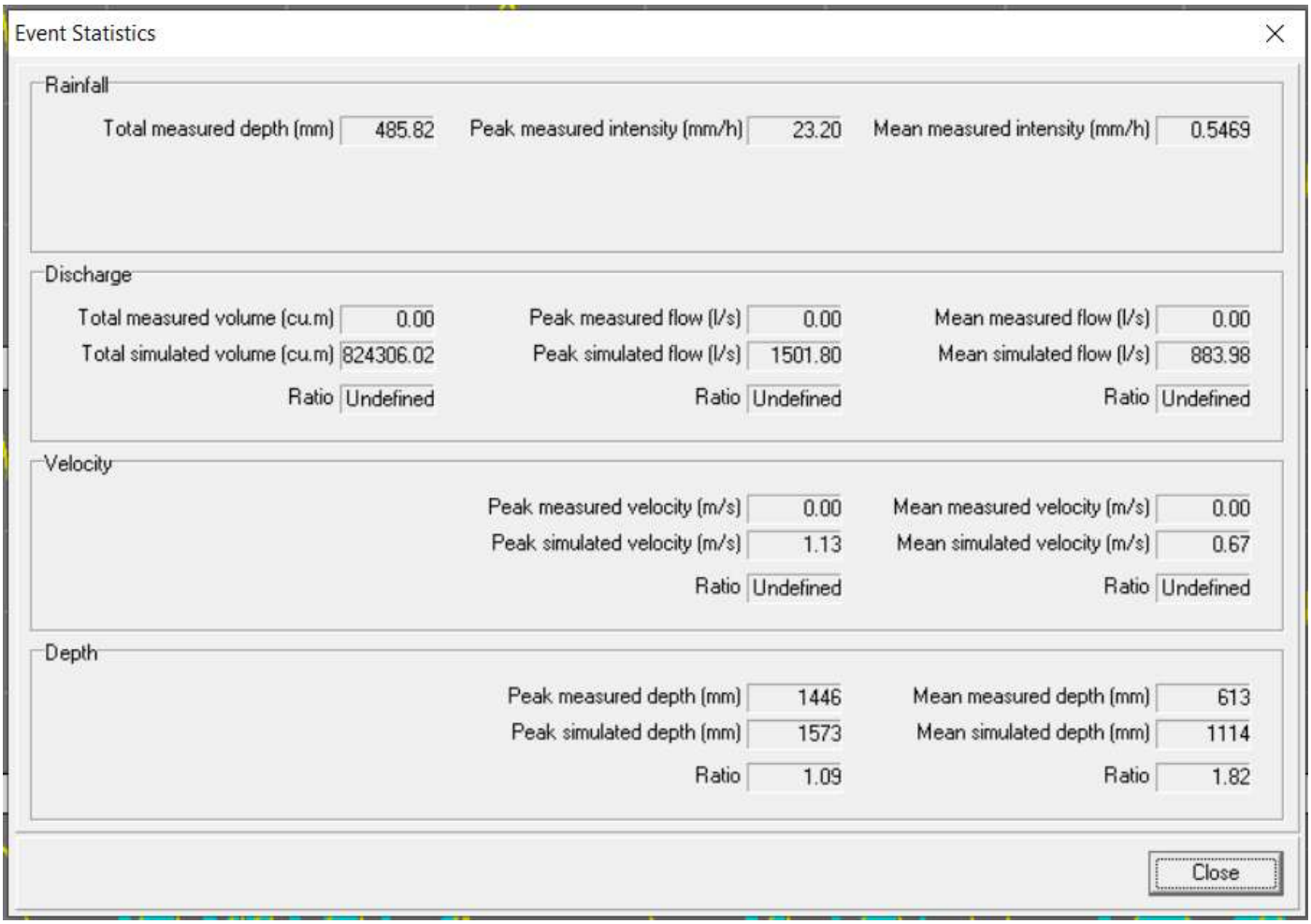
802064 WW3


Gauges | Events | Hydrographs | Scattergraphs | Statistics | Log
Event
WW1
WW2
WW3
SWG
Flow Gauge
802063
802064
802065
802310
Rain Gauge
802049R
802051R
802053R
802303R
Build
Statistics
Options
Print
Print All
Zoom
Zoom Extents
Close
Rainfall (mm/h)
Discharge (l/s)
Velocity (m/s)
Depth (mm)
Date
24/01/2025
Measured
Simulated
16/03/2025

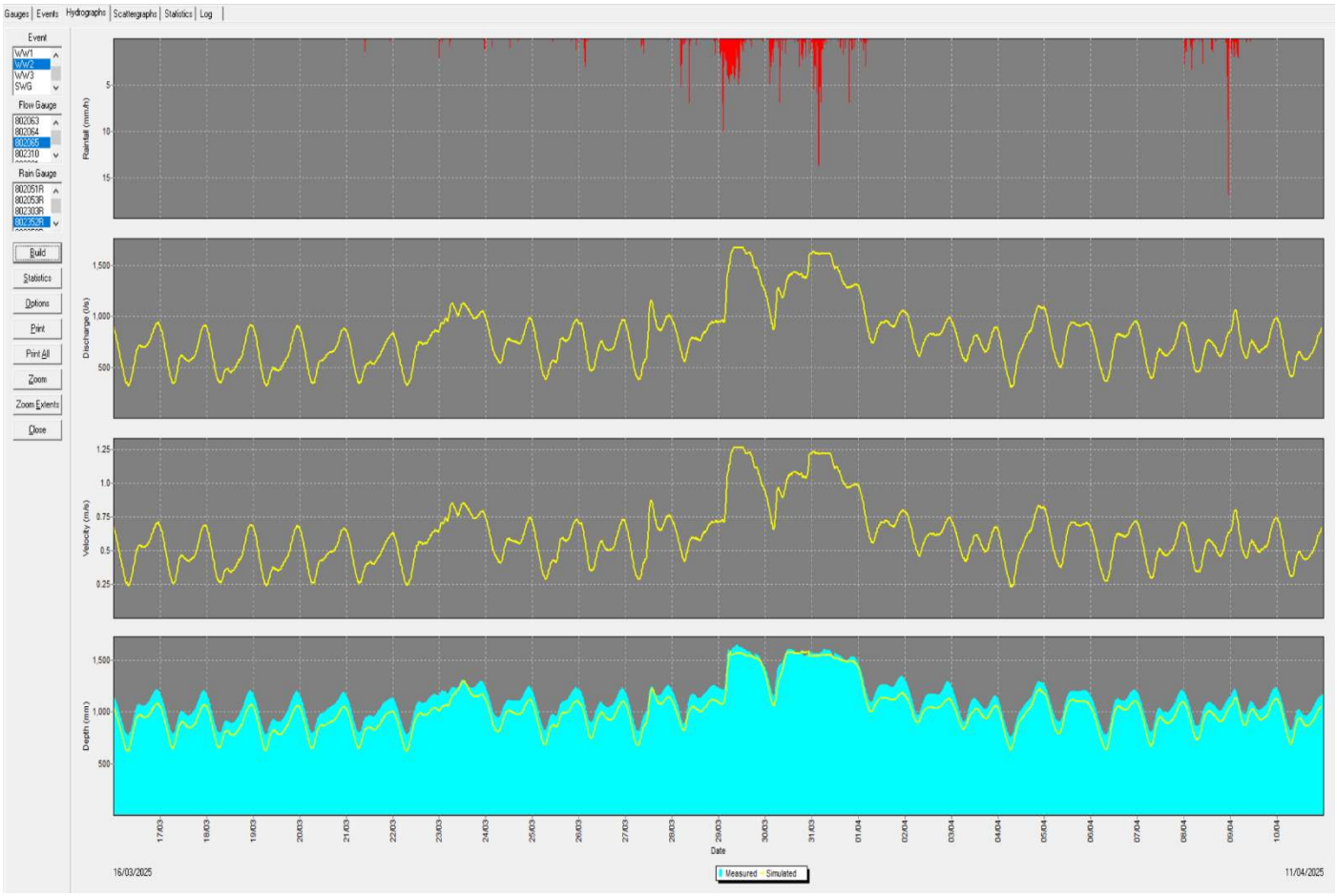

Event Statistics
Rainfall
Total measured depth (mm) 105.46
Peak measured intensity (mm/h) 32.88
Mean measured intensity (mm/h) 0.0861
Discharge
Total measured volume (cu.m) 0.00
Total simulated volume (cu.m) 253445.24
Ratio Undefined
Peak measured flow (l/s) 0.00
Peak simulated flow (l/s) 2938.20
Ratio Undefined
Mean measured flow (l/s) 0.00
Mean simulated flow (l/s) 1646.79
Ratio Undefined
Velocity
Peak measured velocity (m/s) 0.00
Peak simulated velocity (m/s) 0.94
Ratio Undefined
Mean measured velocity (m/s) 0.00
Mean simulated velocity (m/s) 0.53
Ratio Undefined
Depth
Peak measured depth (mm) 1889
Peak simulated depth (mm) 1921
Ratio 1.02
Mean measured depth (mm) 1356
Mean simulated depth (mm) 1176
Ratio 0.87
Close

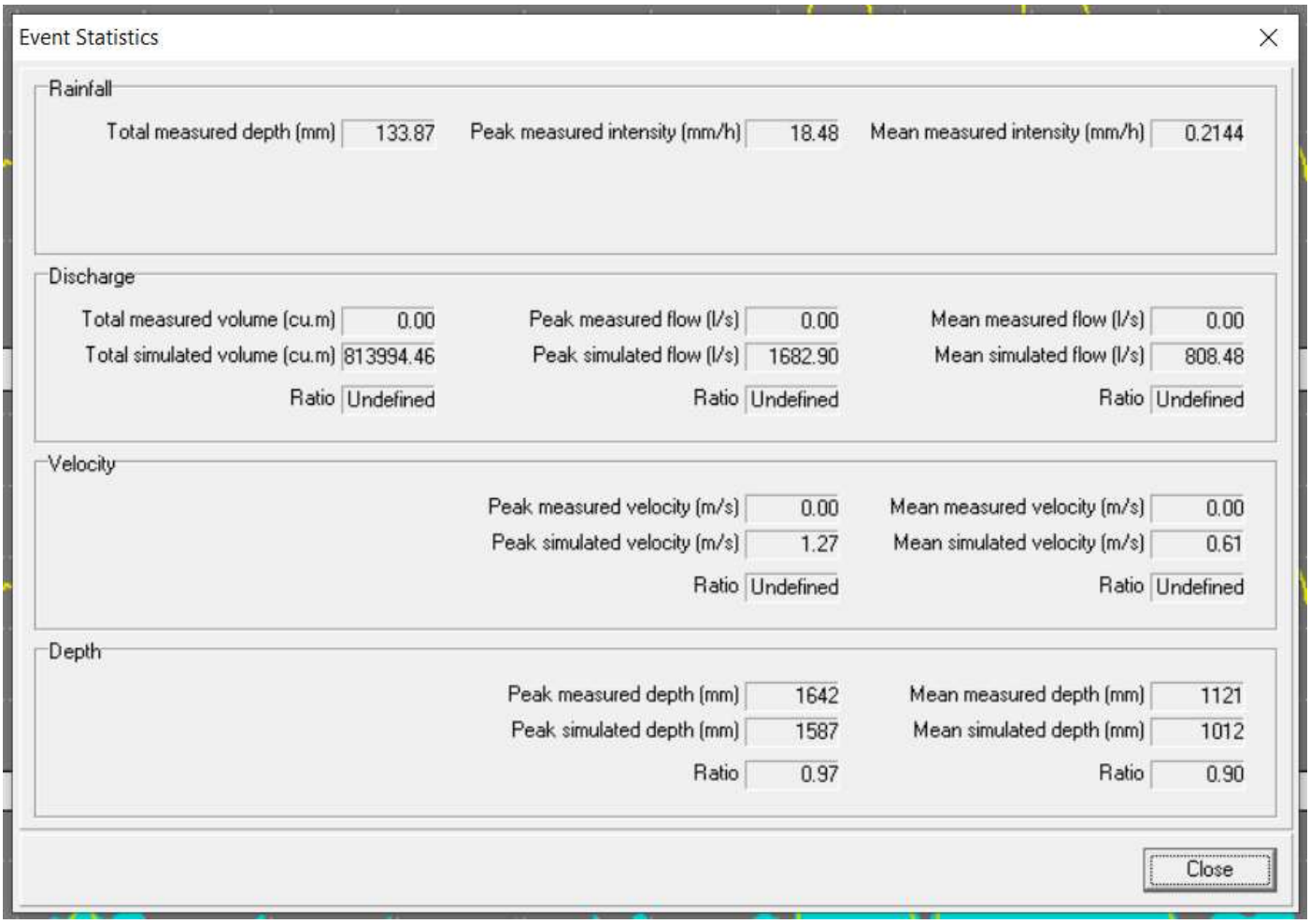
802065 WW1


Gauges | Events | Hydrographs | Scattergraphs | Statistics | Log
Event
WW1
WW2
WW3
SWG
Flow Gauge
802063
802064
802065
802310
Rain Gauge
802051R
802053R
802303R
802352R
Build
Statistics
Options
Print
Print All
Zoom
Zoom Extents
Close
Rainfall (mm/h)
Discharge (l/s)
Velocity (m/s)
Depth (mm)
Date
25/07/2025
31/08/2025
Measured
Simulated

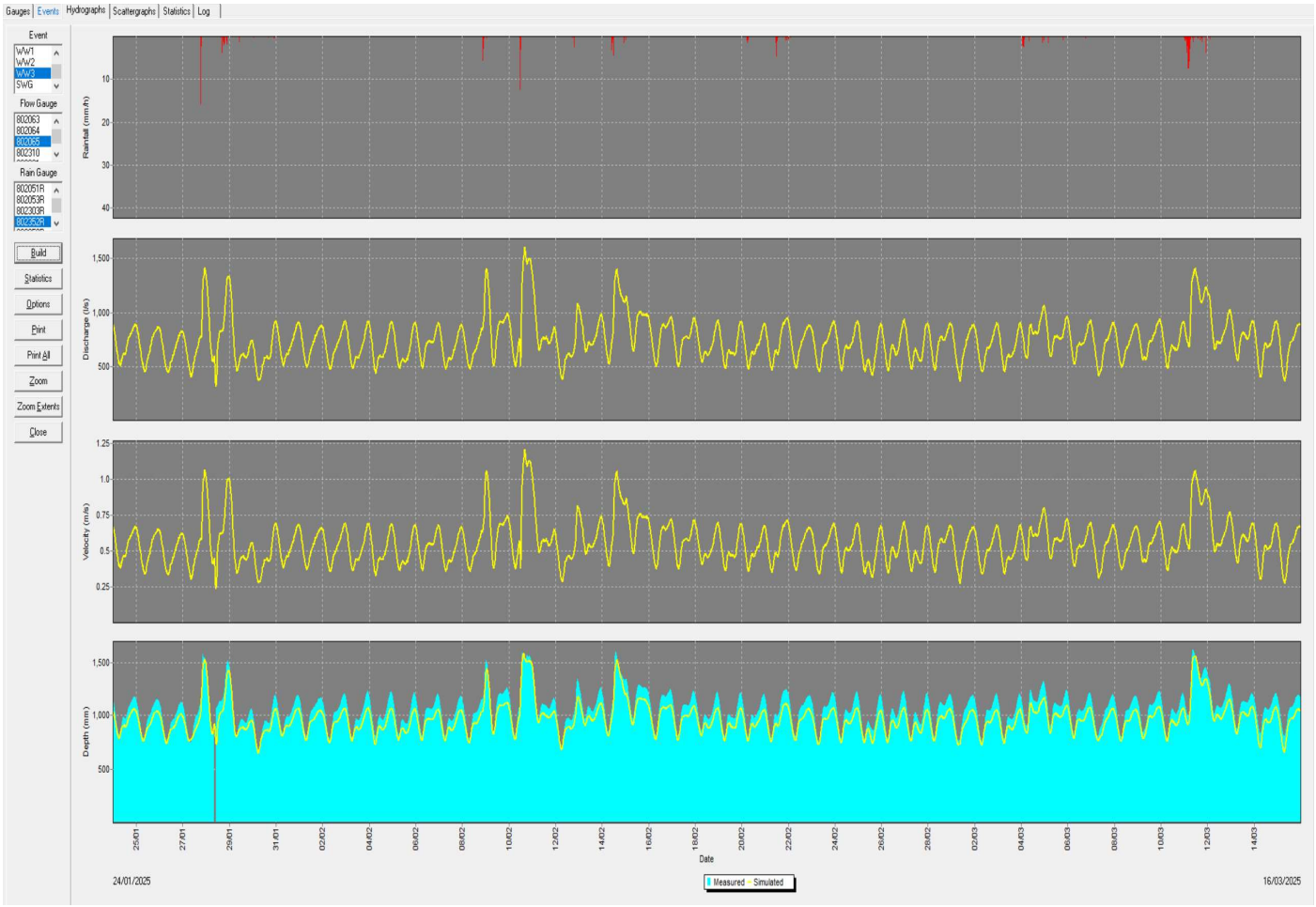

Event Statistics
Rainfall
Total measured depth (mm) 485.82
Peak measured intensity (mm/h) 23.20
Mean measured intensity (mm/h) 0.5469
Discharge
Total measured volume (cu.m) 0.00
Total simulated volume (cu.m) 824306.02
Ratio Undefined
Peak measured flow (l/s) 0.00
Peak simulated flow (l/s) 1501.80
Ratio Undefined
Mean measured flow (l/s) 0.00
Mean simulated flow (l/s) 883.98
Ratio Undefined
Velocity
Peak measured velocity (m/s) 0.00
Peak simulated velocity (m/s) 1.13
Ratio Undefined
Mean measured velocity (m/s) 0.00
Mean simulated velocity (m/s) 0.67
Ratio Undefined
Depth
Peak measured depth (mm) 1446
Peak simulated depth (mm) 1573
Ratio 1.09
Mean measured depth (mm) 613
Mean simulated depth (mm) 1114
Ratio 1.82
Close

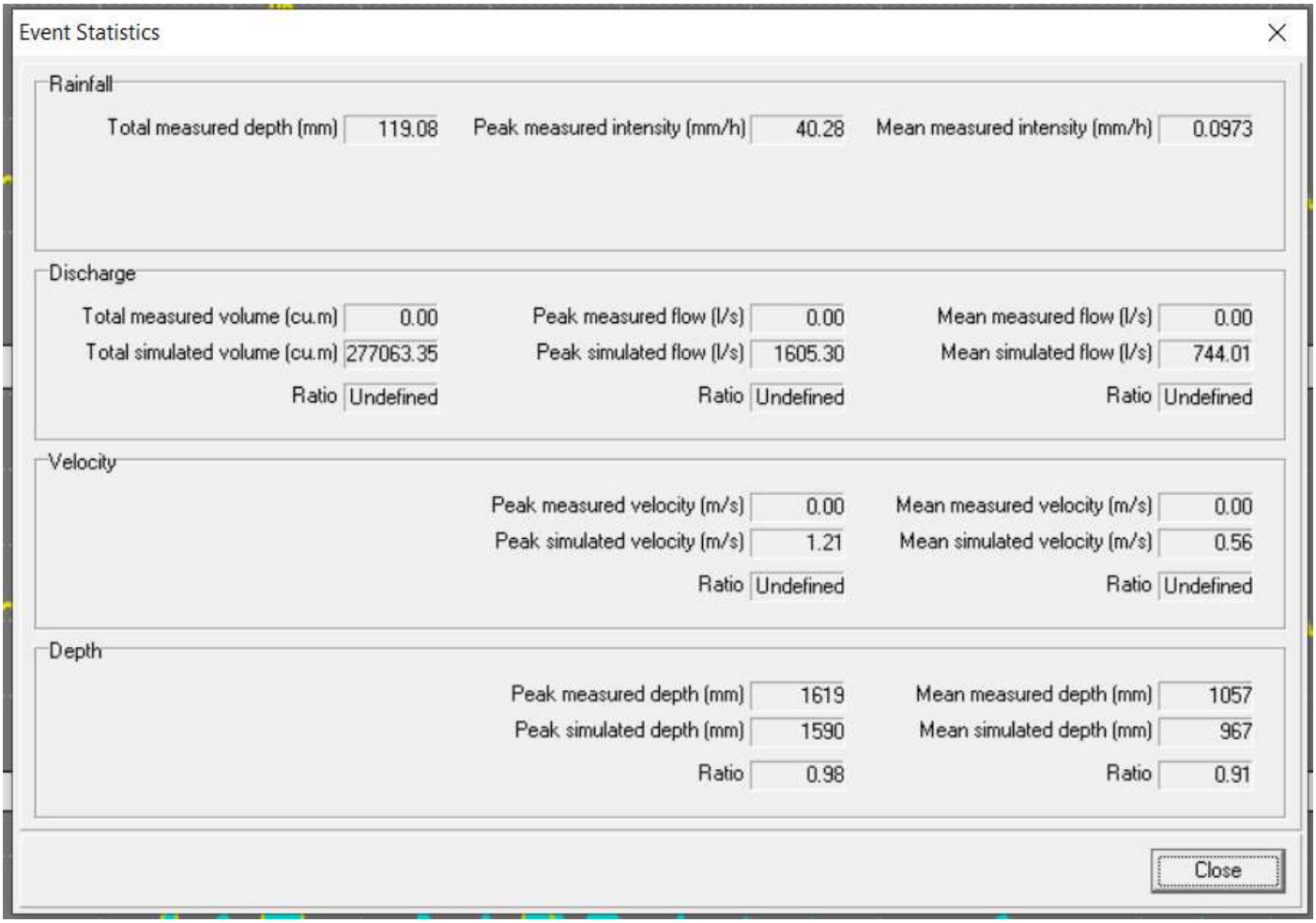
802065 WW2


Gauges | Events | Hydrographs | Scattergraphs | Statistics | Log
Event
WW1
WW2
WW3
SWG
Flow Gauge
802063
802064
802065
802310
Rain Gauge
802051R
802053R
802310R
802353R
Build
Statistics
Options
Print
Print All
Zoom
Zoom Extents
Close
Rainfall (mm/h)
Discharge (l/s)
Velocity (m/s)
Depth (mm)
Date
16/03/2025
11/04/2025
Measured
Simulated

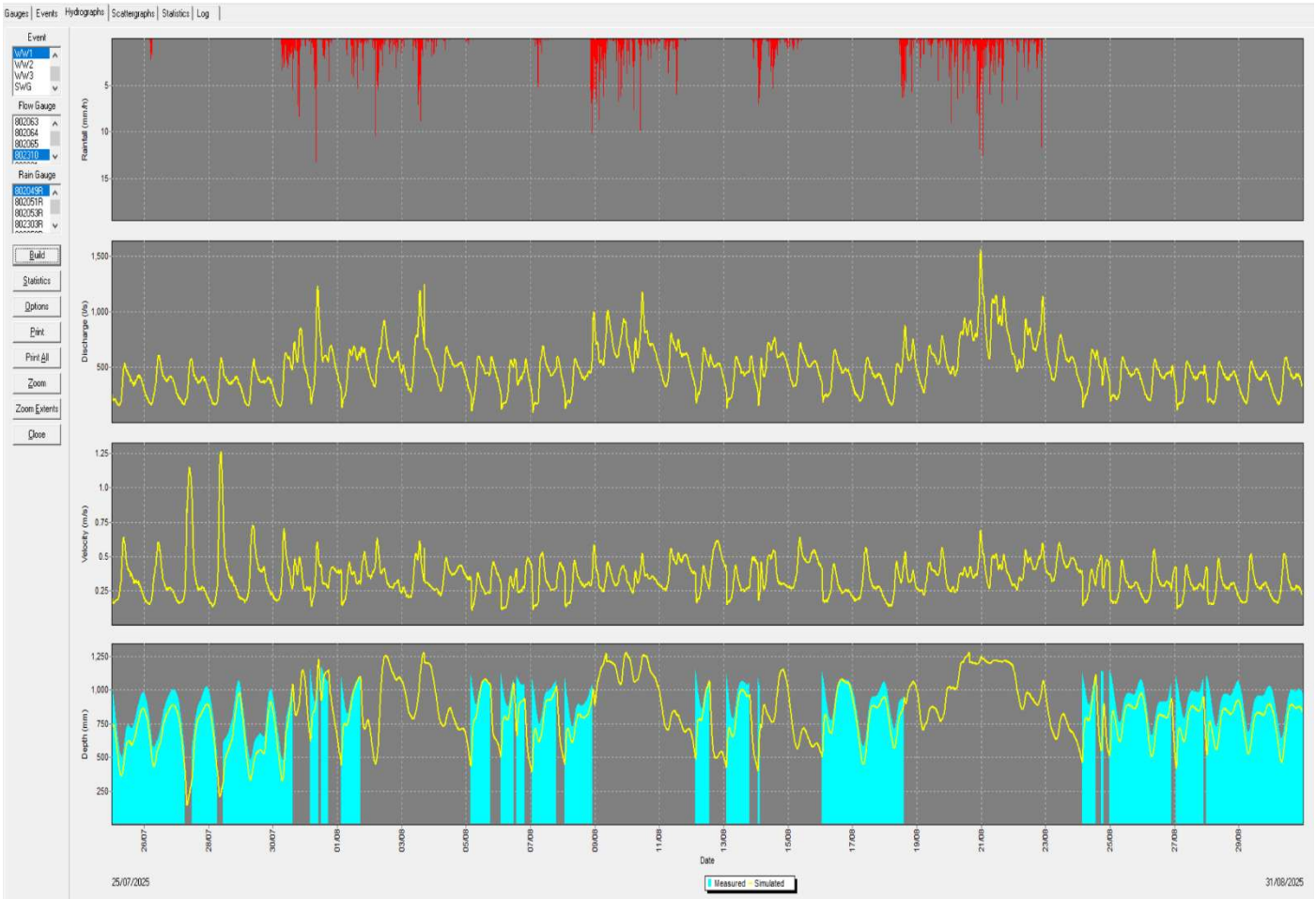

Event Statistics
Rainfall
Total measured depth (mm) 133.87
Peak measured intensity (mm/h) 18.48
Mean measured intensity (mm/h) 0.2144
Discharge
Total measured volume (cu.m) 0.00
Peak measured flow (l/s) 0.00
Mean measured flow (l/s) 0.00
Total simulated volume (cu.m) 813994.46
Peak simulated flow (l/s) 1682.90
Mean simulated flow (l/s) 808.48
Ratio Undefined
Ratio Undefined
Ratio Undefined
Velocity
Peak measured velocity (m/s) 0.00
Mean measured velocity (m/s) 0.00
Peak simulated velocity (m/s) 1.27
Mean simulated velocity (m/s) 0.61
Ratio Undefined
Ratio Undefined
Depth
Peak measured depth (mm) 1642
Mean measured depth (mm) 1121
Peak simulated depth (mm) 1587
Mean simulated depth (mm) 1012
Ratio 0.97
Ratio 0.90
Close

802065 WW3


Gauges | Events | Hydrographs | Scattergraphs | Statistics | Log
Event
WW1
WW2
WW3
SWG
Flow Gauge
802063
802064
802065
802310
Rain Gauge
802051R
802053R
802303R
802526R
Build
Statistics
Options
Print
Print All
Zoom
Zoom Extents
Close
Rainfall (mm/h)
Discharge (l/s)
Velocity (m/s)
Depth (mm)
Date
24/01/2025
Measured
Simulated
16/03/2025

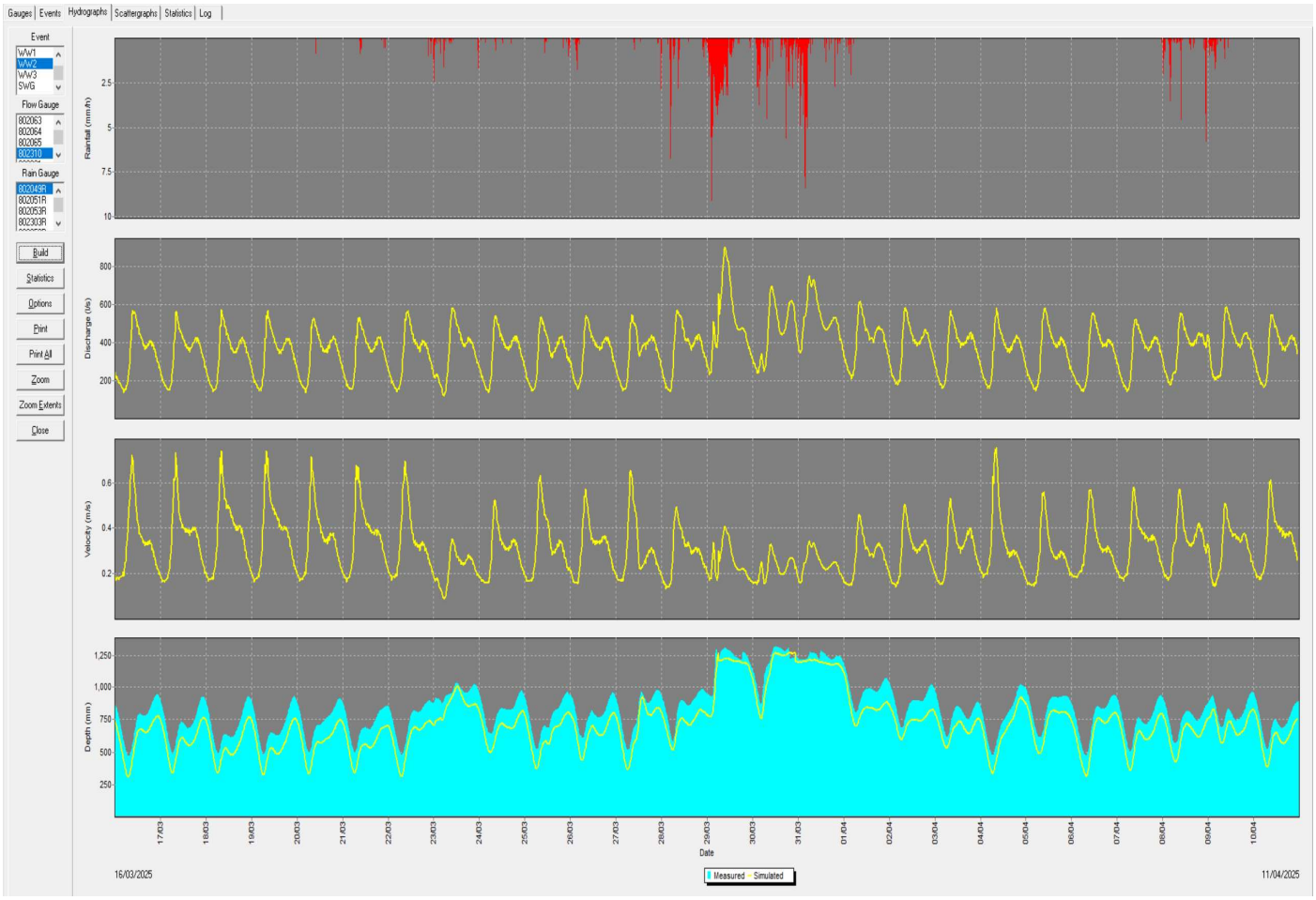

Event Statistics
Rainfall
Total measured depth (mm) 119.08
Peak measured intensity (mm/h) 40.28
Mean measured intensity (mm/h) 0.0973
Discharge
Total measured volume (cu.m) 0.00
Peak measured flow (l/s) 0.00
Mean measured flow (l/s) 0.00
Total simulated volume (cu.m) 277063.35
Peak simulated flow (l/s) 1605.30
Mean simulated flow (l/s) 744.01
Ratio Undefined
Ratio Undefined
Ratio Undefined
Velocity
Peak measured velocity (m/s) 0.00
Mean measured velocity (m/s) 0.00
Peak simulated velocity (m/s) 1.21
Mean simulated velocity (m/s) 0.56
Ratio Undefined
Ratio Undefined
Depth
Peak measured depth (mm) 1619
Mean measured depth (mm) 1057
Peak simulated depth (mm) 1590
Mean simulated depth (mm) 967
Ratio 0.98
Ratio 0.91
Close

802310 WW1


Gauges | Events | Hydrographs | Scattergraphs | Statistics | Log
Event
WW1
WW2
WW3
SWG
Flow Gauge
802063
802064
802065
802310
Rain Gauge
802049R
802051R
802053R
802303R
Build
Statistics
Options
Print
Print All
Zoom
Zoom Extents
Close
Rainfall (mm/h)
Discharge (l/s)
Velocity (m/s)
Depth (mm)
Date
25/07/2025
31/08/2025
Measured
Simulated

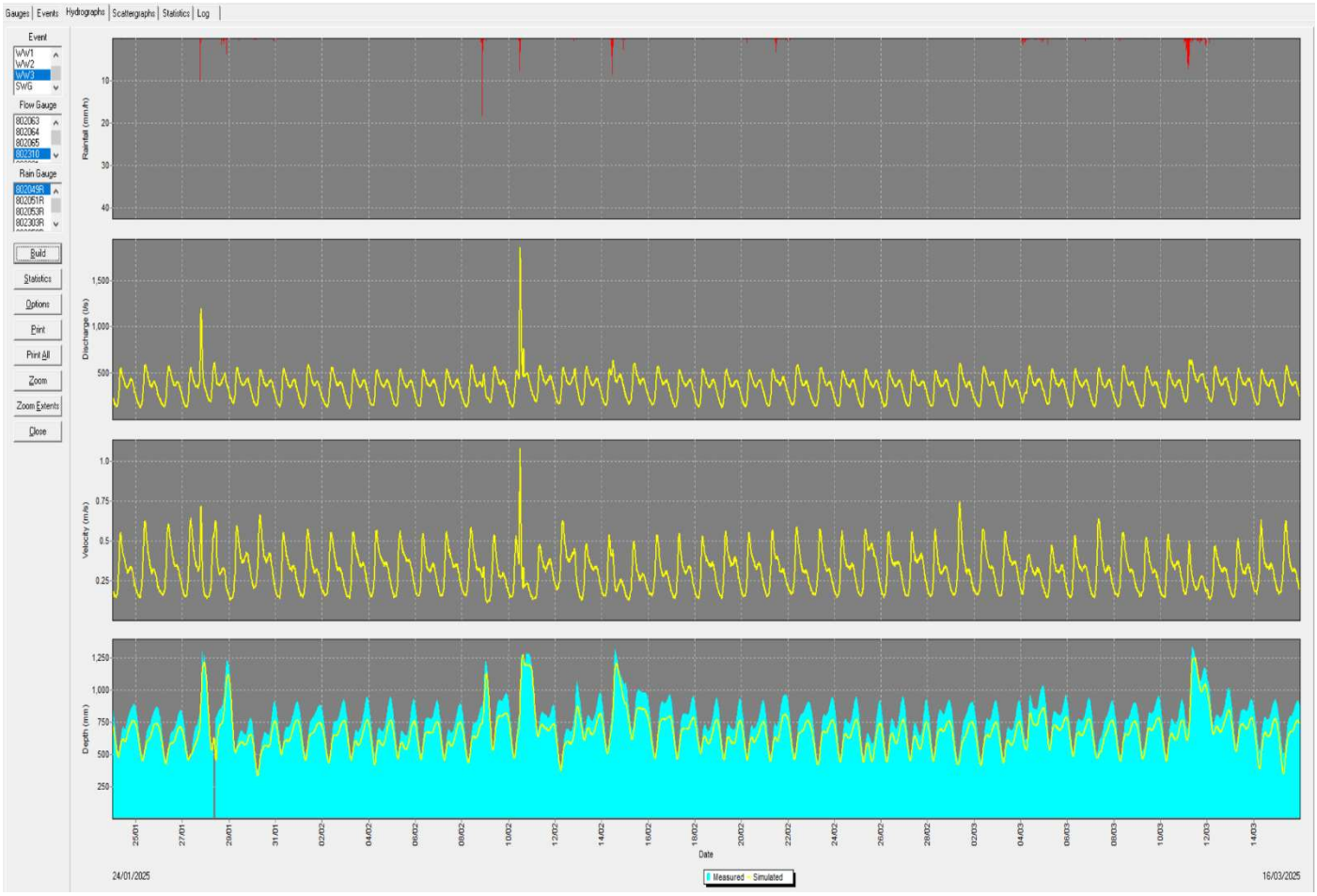

Event Statistics
Rainfall
Total measured depth (mm) 443.13
Peak measured intensity (mm/h) 18.60
Mean measured intensity (mm/h) 0.4989
Discharge
Total measured volume (cu.m) 0.00
Total simulated volume (cu.m) 567630.08
Ratio Undefined
Peak measured flow (l/s) 0.00
Peak simulated flow (l/s) 1561.10
Ratio Undefined
Mean measured flow (l/s) 0.00
Mean simulated flow (l/s) 490.65
Ratio Undefined
Velocity
Peak measured velocity (m/s) 0.00
Peak simulated velocity (m/s) 1.26
Ratio Undefined
Mean measured velocity (m/s) 0.00
Mean simulated velocity (m/s) 0.34
Ratio Undefined
Depth
Peak measured depth (mm) 1180
Peak simulated depth (mm) 1278
Ratio 1.08
Mean measured depth (mm) 470
Mean simulated depth (mm) 822
Ratio 1.75
Close

802310 WW2


Gauges | Events | Hydrographs | Scattergraphs | Statistics | Log
Event
WW1
WW2
WW3
SWG
Flow Gauge
802063
802064
802065
802310
Rain Gauge
802048R
802051R
802053R
802303R
Build
Statistics
Options
Print
Print All
Zoom
Zoom Extents
Close
Rainfall (mm/h)
Discharge (l/s)
Velocity (m/s)
Depth (mm)
Date
16/03/2025
11/04/2025
Measured
Simulated


Event Statistics
Rainfall
Total measured depth (mm) 115.83
Peak measured intensity (mm/h) 9.60
Mean measured intensity (mm/h) 0.1856
Discharge
Total measured volume (cu.m) 0.00
Total simulated volume (cu.m) 837591.30
Ratio Undefined
Peak measured flow (l/s) 0.00
Peak simulated flow (l/s) 903.30
Ratio Undefined
Mean measured flow (l/s) 0.00
Mean simulated flow (l/s) 373.31
Ratio Undefined
Velocity
Peak measured velocity (m/s) 0.00
Peak simulated velocity (m/s) 0.75
Ratio Undefined
Mean measured velocity (m/s) 0.00
Mean simulated velocity (m/s) 0.31
Ratio Undefined
Depth
Peak measured depth (mm) 1322
Peak simulated depth (mm) 1278
Ratio 0.97
Mean measured depth (mm) 839
Mean simulated depth (mm) 714
Ratio 0.85
Close

802310 WW3


Gauges | Events | Hydrographs | Scattergraphs | Statistics | Log
Event
WW1
WW2
WW3
SWG
Flow Gauge
802063
802064
802065
802310
Rain Gauge
802049R
802051R
802053R
802303R
Build
Statistics
Options
Print
Print All
Zoom
Zoom Extents
Close
Rainfall (mm/h)
Discharge (l/s)
Velocity (m/s)
Depth (mm)
Date
24/01/2025
Measured
Simulated
16/03/2025


Event Statistics
Rainfall
Total measured depth (mm) 121.82
Peak measured intensity (mm/h) 40.64
Mean measured intensity (mm/h) 0.0995
Discharge
Total measured volume (cu.m) 0.00
Peak measured flow (l/s) 0.00
Mean measured flow (l/s) 0.00
Total simulated volume (cu.m) 571252.58
Peak simulated flow (l/s) 1851.90
Mean simulated flow (l/s) 356.73
Ratio Undefined
Ratio Undefined
Ratio Undefined
Velocity
Peak measured velocity (m/s) 0.00
Mean measured velocity (m/s) 0.00
Peak simulated velocity (m/s) 1.08
Mean simulated velocity (m/s) 0.31
Ratio Undefined
Ratio Undefined
Depth
Peak measured depth (mm) 1332
Mean measured depth (mm) 776
Peak simulated depth (mm) 1277
Mean simulated depth (mm) 670
Ratio 0.96
Ratio 0.86
Close

Attachment 4 Bias Test (SWAGMAN) Analysis

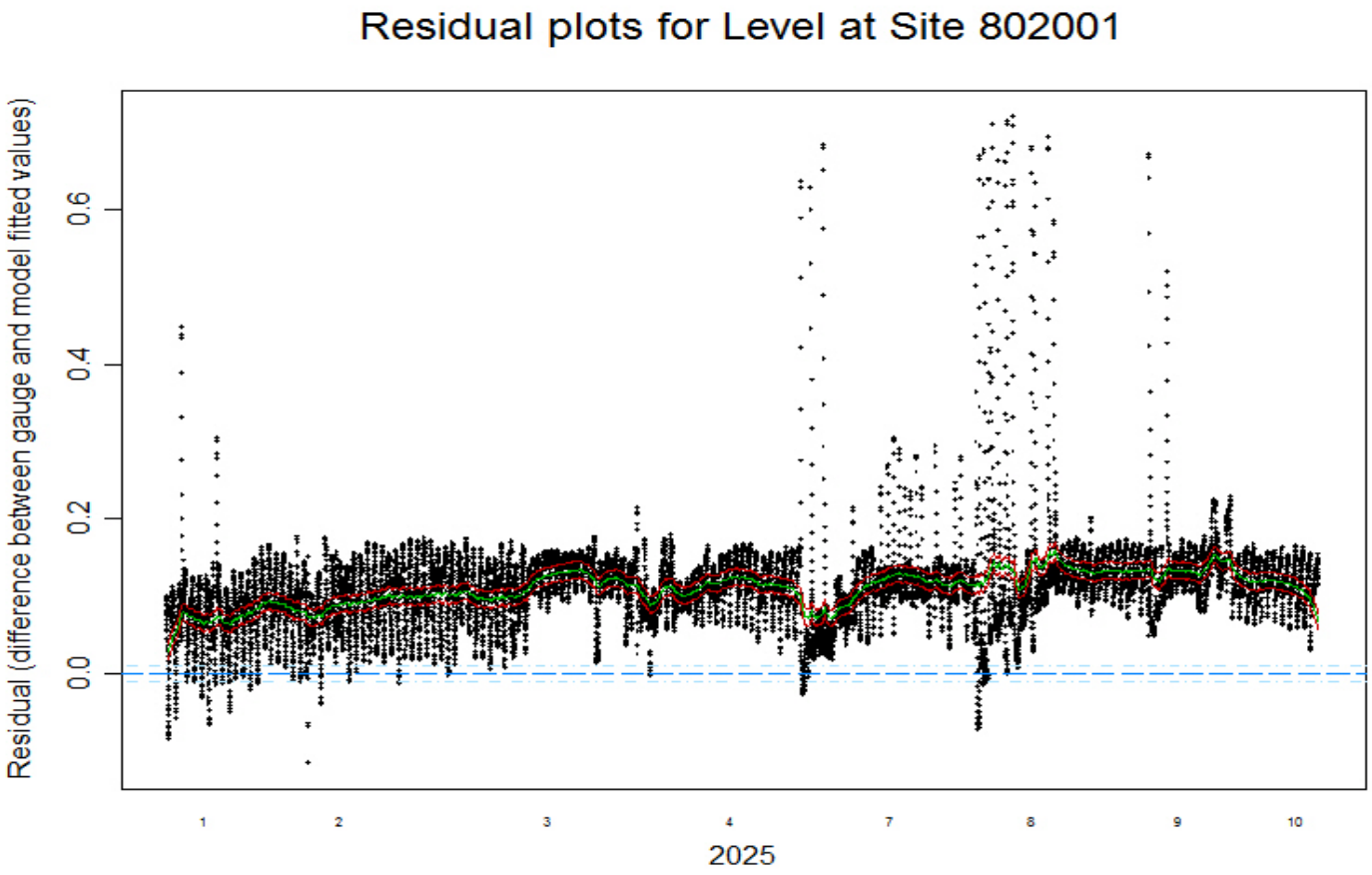
Level Report for Station 802001

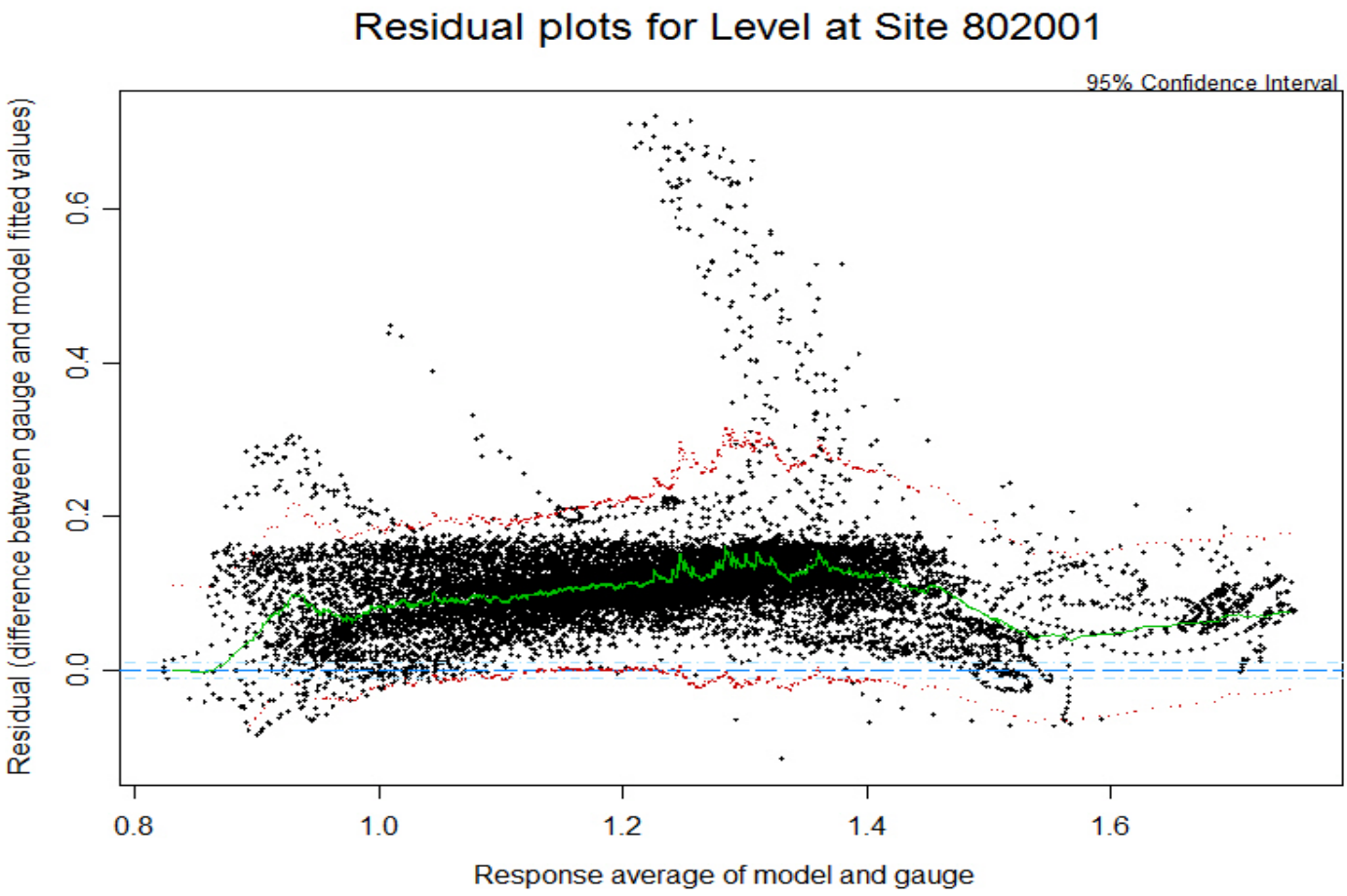
Gauge filename: R:\Wwdih\Palms\Sts\Malabar\Swagman/G802001L.txt (19030 observations)
Model filename: R:\Wwdih\Palms\Sts\Malabar\Swagman/M802001L.txt (32925 observations)

15672 observations in matched dataset.

Criteria Values for assessing model performance
==========

	all observations	specified region (1.1958 to 1.4093)
MSE	0.0158	0.0148
R abs	0.14	-1.26
R squared	0.87	0.76
R sq (lag gauge)	0.86	
R sq (lag model)	0.88	
adjusted R sq	0.40	-3.07
adjusted R sq (lag gauge)	0.39	
adjusted R sq (lag model)	0.41	





Report date 08/01/2026 16:20

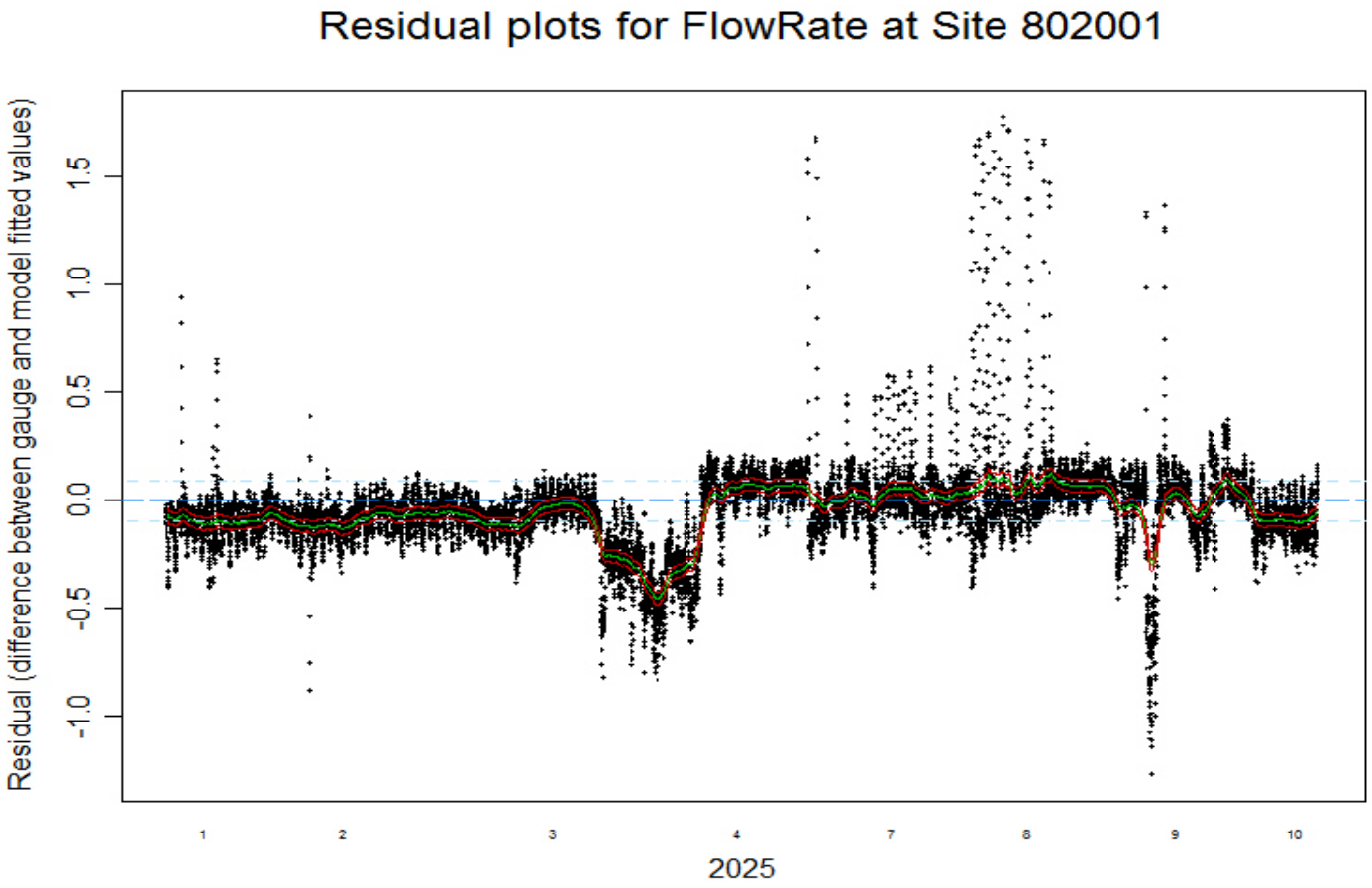
Flow Report for Station 802001

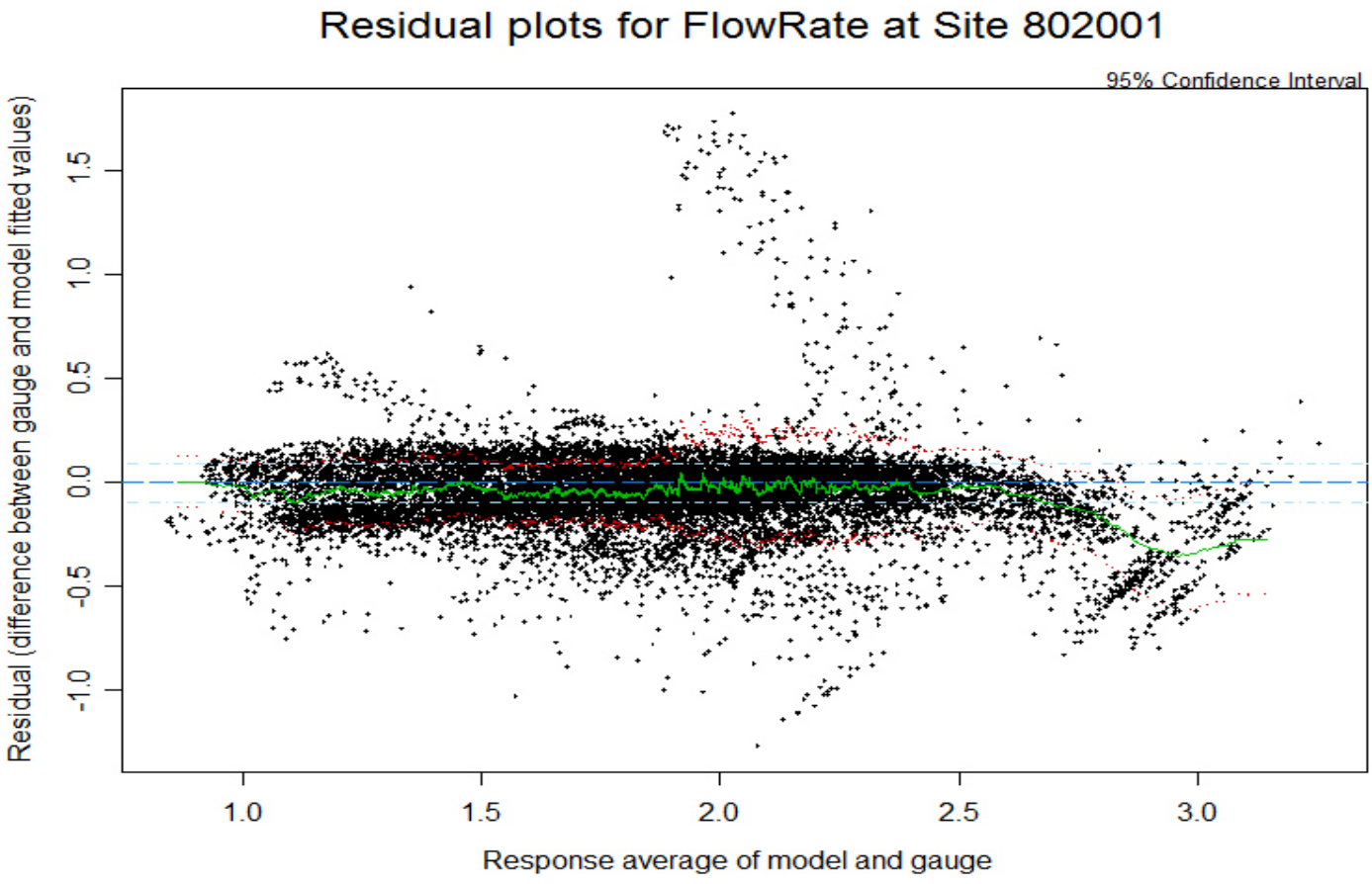
Gauge filename: R:\Wwdih\Palms\Sts\Malabar\Swagman/G802001Q.txt (19030 observations)
Model filename: R:\Wwdih\Palms\Sts\Malabar\Swagman/M802001Q.txt (32925 observations)

15457 observations in matched dataset.

Criteria Values for assessing model performance
==========

	all observations	specified region (1.613704 to 2.198418)
MSE	0.0396	0.0242
R abs	0.63	0.23
R squared	0.82	0.5
R sq (lag gauge)	0.81	
R sq (lag model)	0.81	
adjusted R sq	0.78	0.06
adjusted R sq (lag gauge)	0.78	
adjusted R sq (lag model)	0.78	





Report date 08/01/2026 16:20

Level Report for Station 802051N

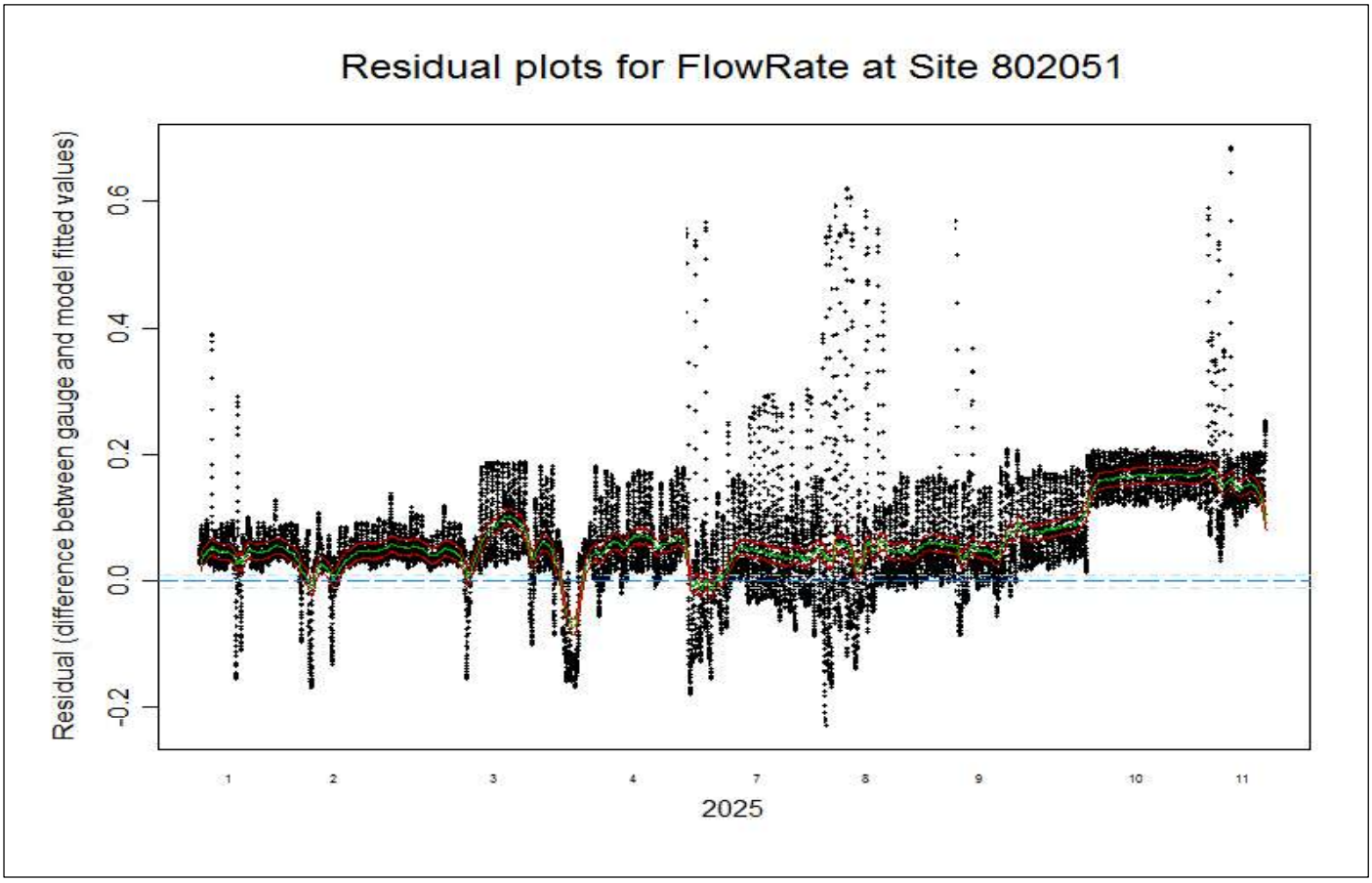
Gauge filename: R:\Wwdih\Palms\Sts\Malabar\Swagman/G802051NL.txt (19030 observations)
Model filename: R:\Wwdih\Palms\Sts\Malabar\Swagman/M802051NL.txt (32925 observations)

18837 observations in matched dataset.

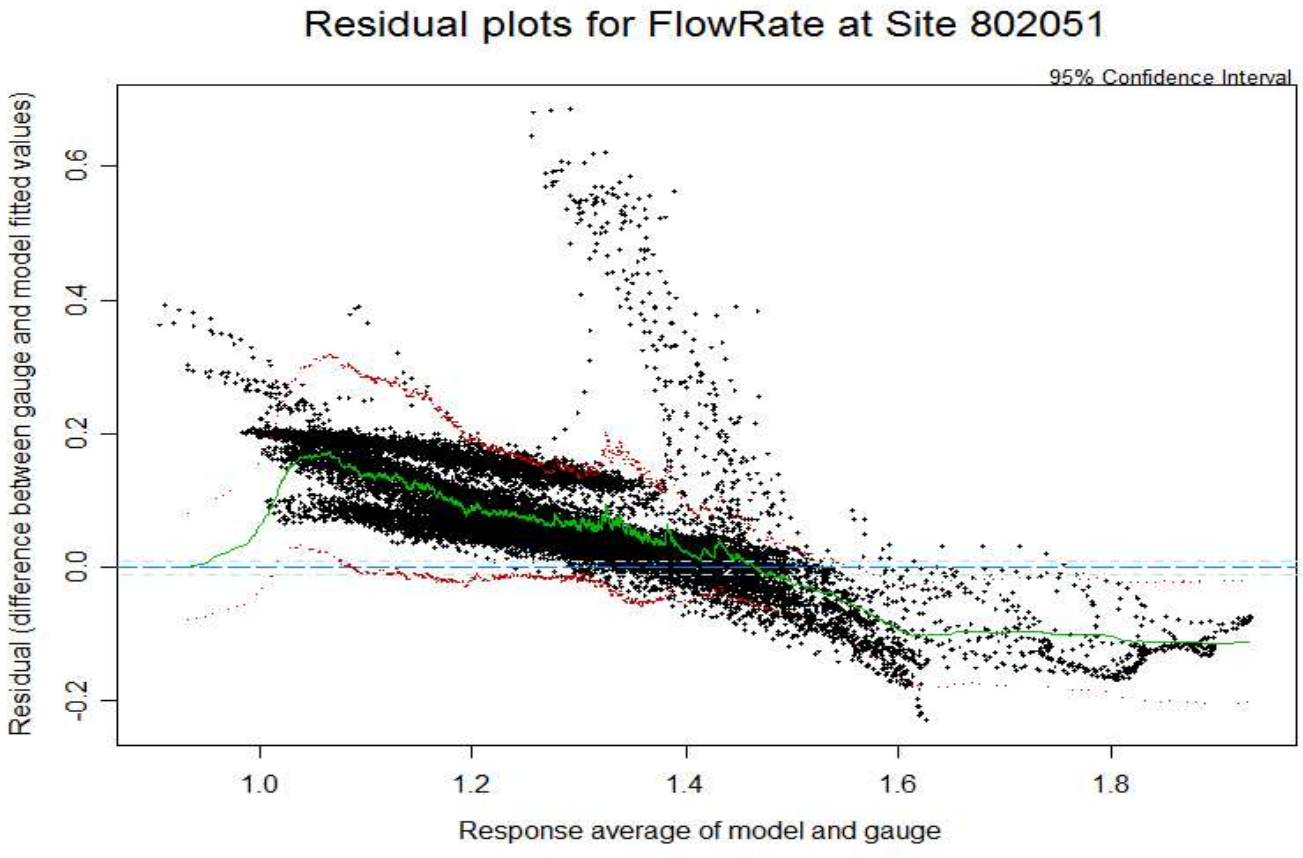
Criteria Values for assessing model performance
==========

	all observations	specified region (1.2465 to 1.4107)
MSE	0.0112	0.006
R abs	0.16	-0.55
R squared	0.86	0.66
R sq (lag gauge)	0.85	
R sq (lag model)	0.85	
adjusted R sq	0.27	-1.82
adjusted R sq (lag gauge)	0.26	
adjusted R sq (lag model)	0.26	

Residual Plots for Level at Site 802051N:



Residual Plots for Level at Site 802051N:



Report date 08/01/2026 16:20

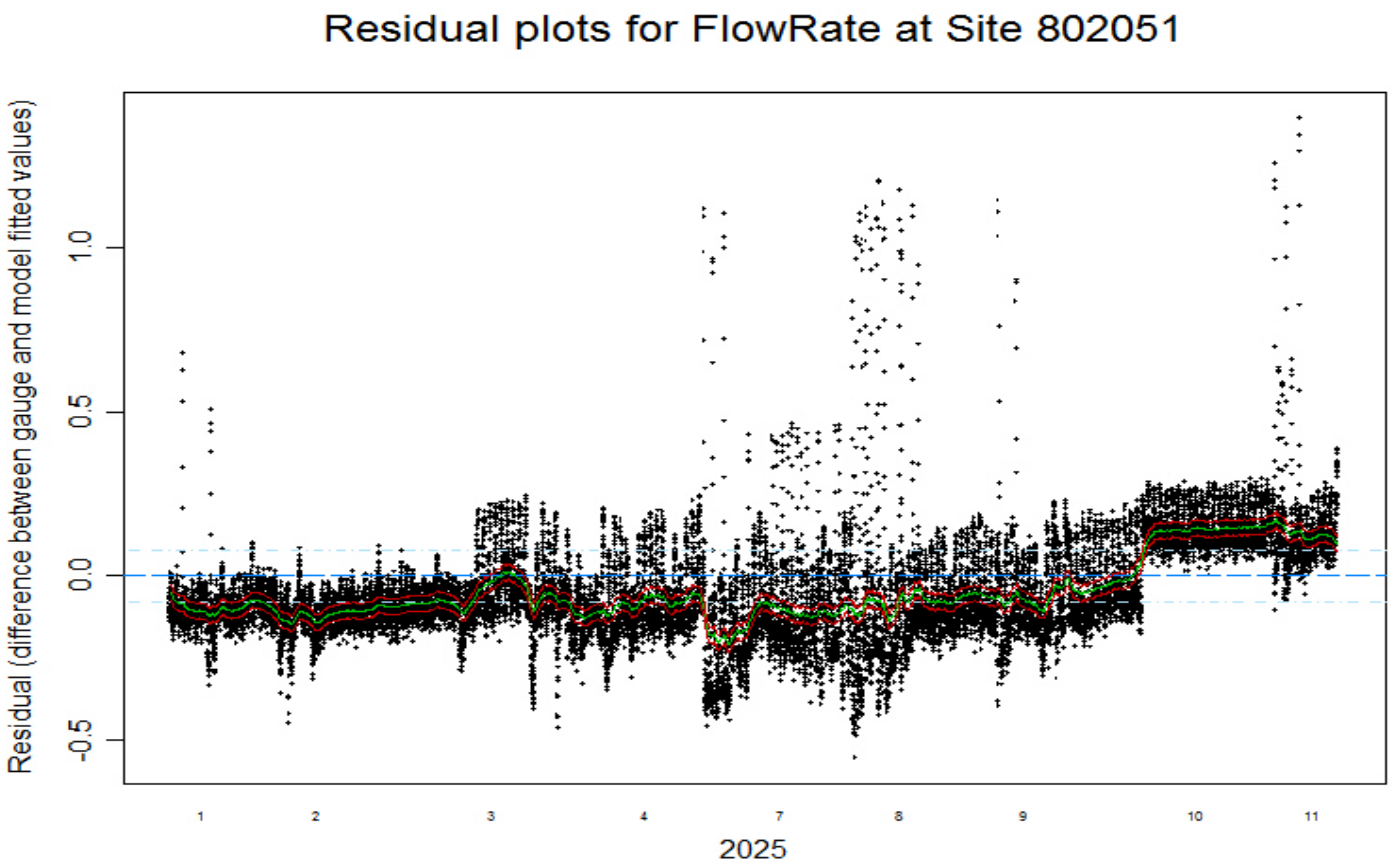
Flow Report for Station 802051N

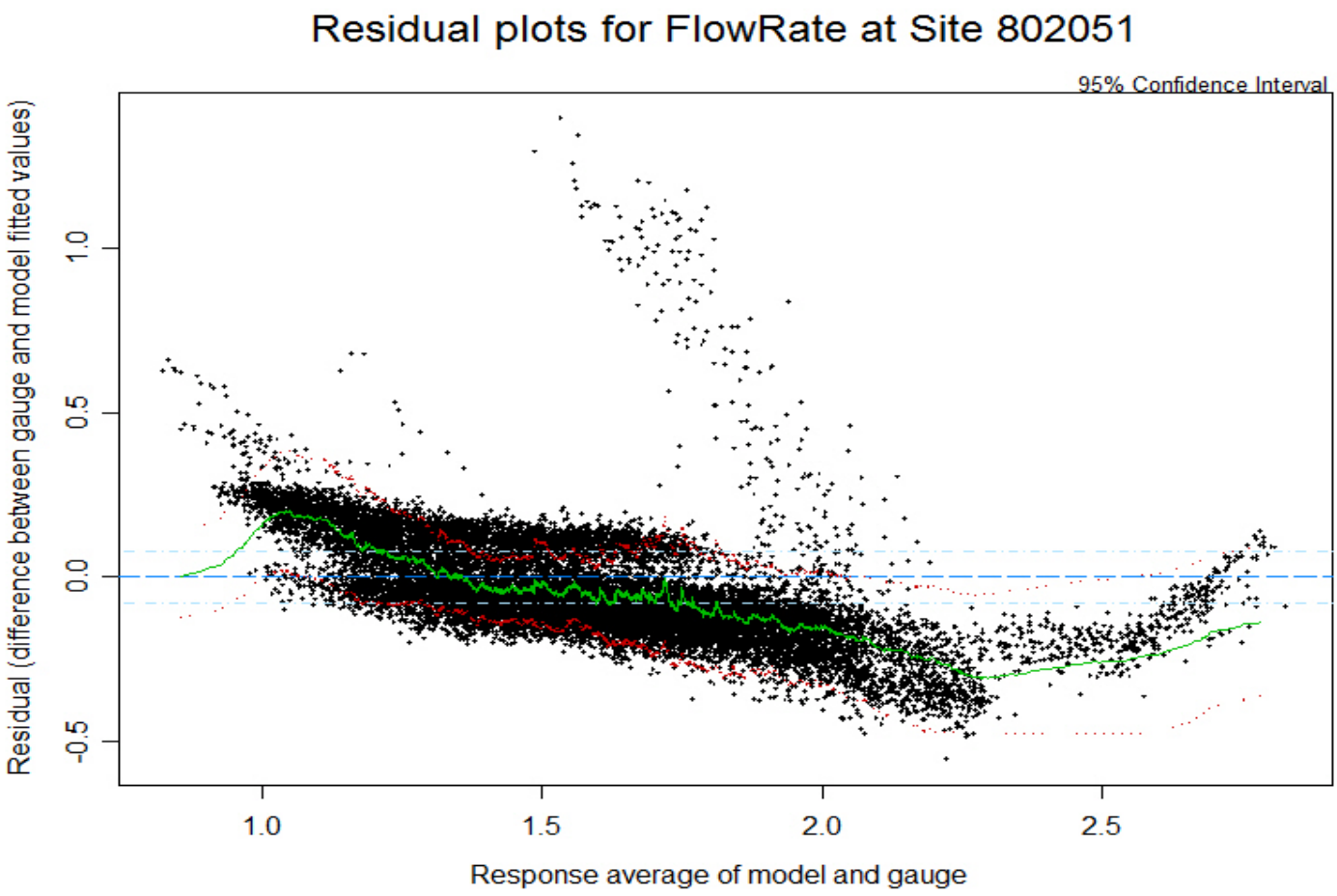
Gauge filename: R:\Wwdih\Palms\Sts\Malabar\Swagman/G802051NQ.txt (19030 observations)
Model filename: R:\Wwdih\Palms\Sts\Malabar\Swagman/M802051NQ.txt (32925 observations)

18837 observations in matched dataset.

Criteria Values for assessing model performance
==========

	all observations	specified region (1.406578 to 1.790018)
MSE	0.0263	0.0149
R abs	0.42	-0.15
R squared	0.85	0.64
R sq (lag gauge)	0.84	
R sq (lag model)	0.86	
adjusted R sq	0.67	-0.26
adjusted R sq (lag gauge)	0.65	
adjusted R sq (lag model)	0.67	





Report date 08/01/2026 16:20

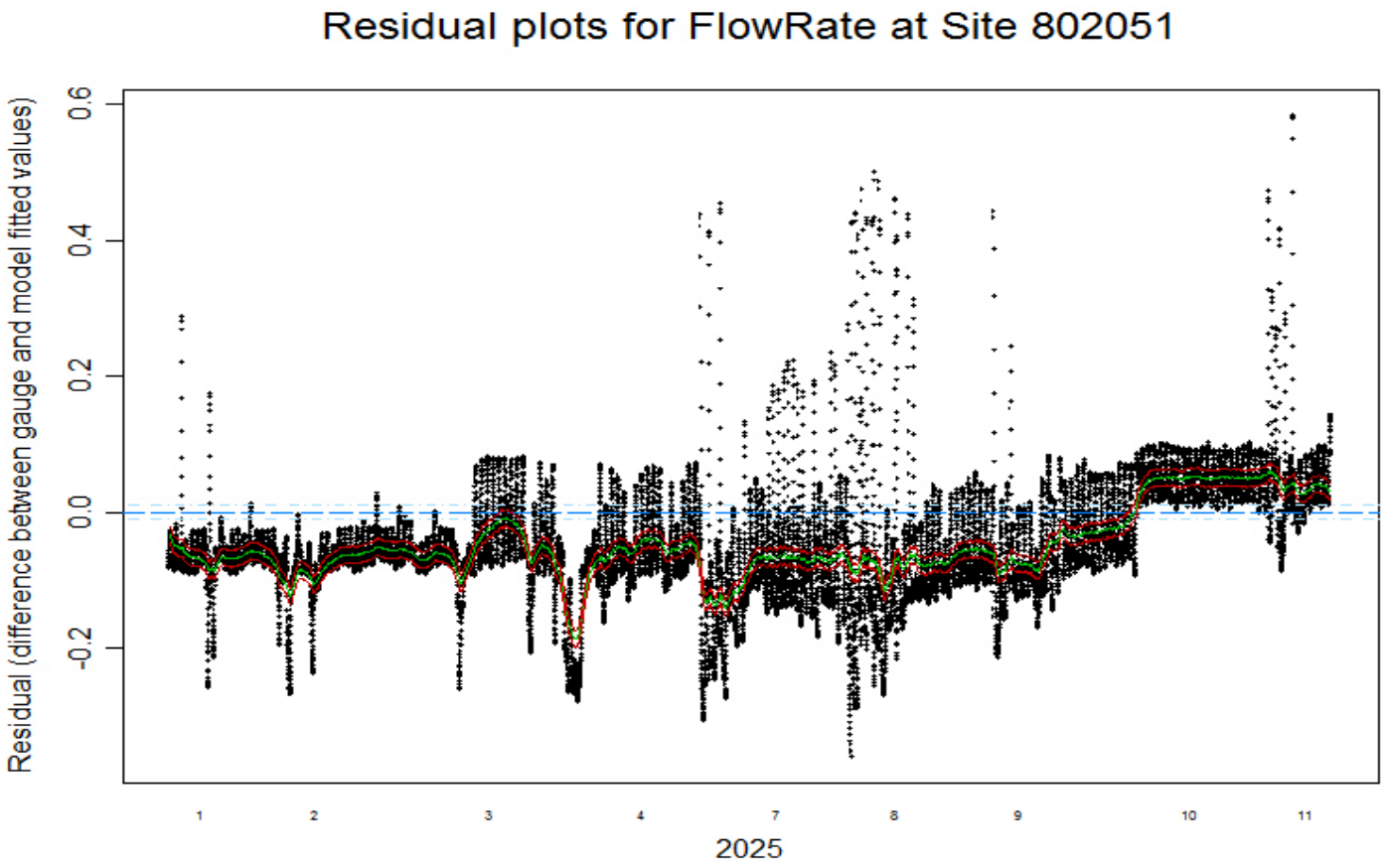
Level Report for Station 802051S

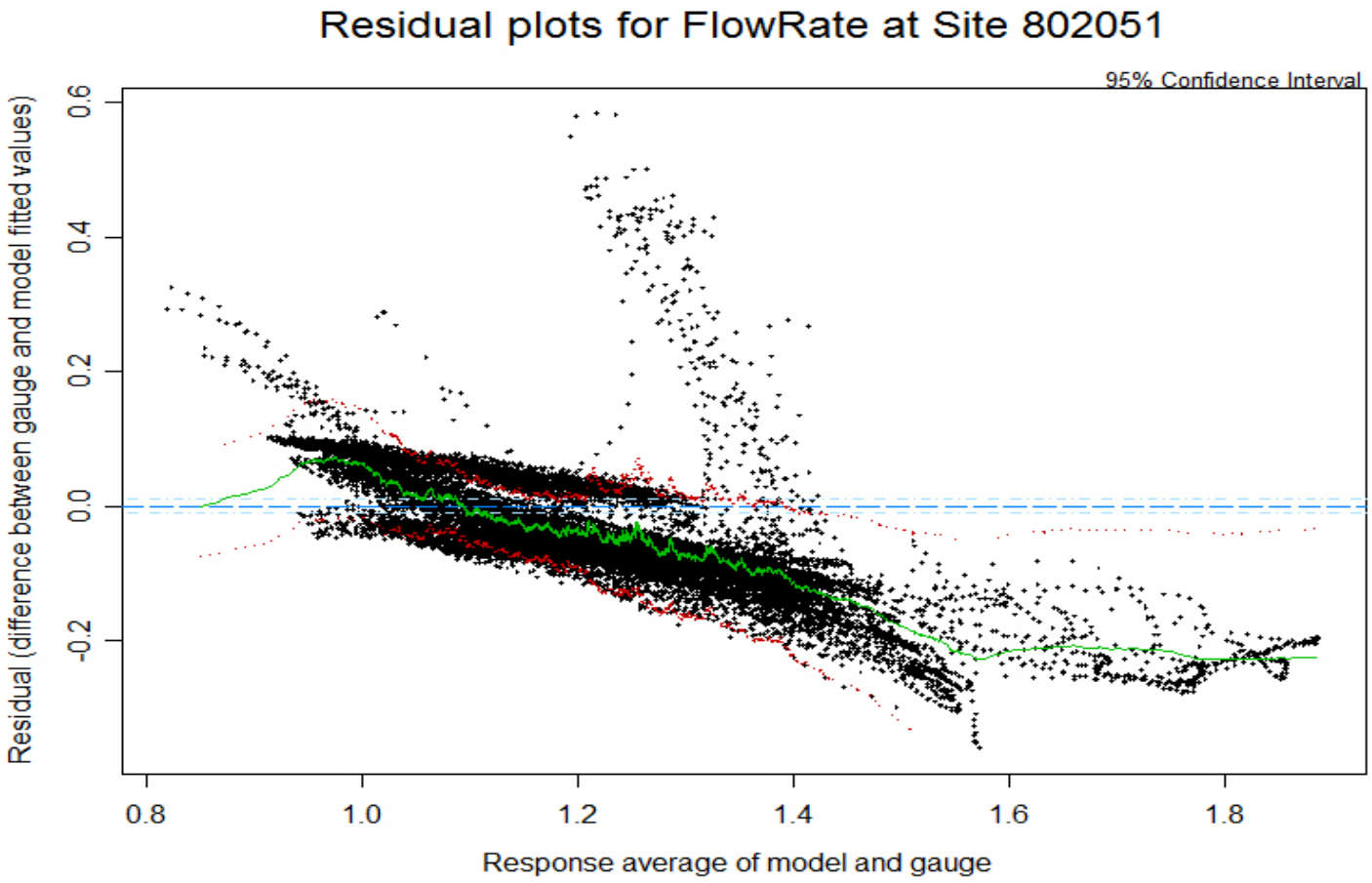
Gauge filename: R:\Wwdih\Palms\Sts\Malabar\Swagman/G802051SL.txt (19030 observations)
Model filename: R:\Wwdih\Palms\Sts\Malabar\Swagman/M802051SL.txt (32925 observations)

18837 observations in matched dataset.

Criteria Values for assessing model performance
==========

	all observations	specified region (1.1283 to 1.2952)
MSE	0.0092	0.0053
R abs	0.21	-0.61
R squared	0.86	0.67
R sq (lag gauge)	0.86	
R sq (lag model)	0.86	
adjusted R sq	0.42	-1.38
adjusted R sq (lag gauge)	0.41	
adjusted R sq (lag model)	0.41	





Report date 08/01/2026 16:20

Flow Report for Station 802051S

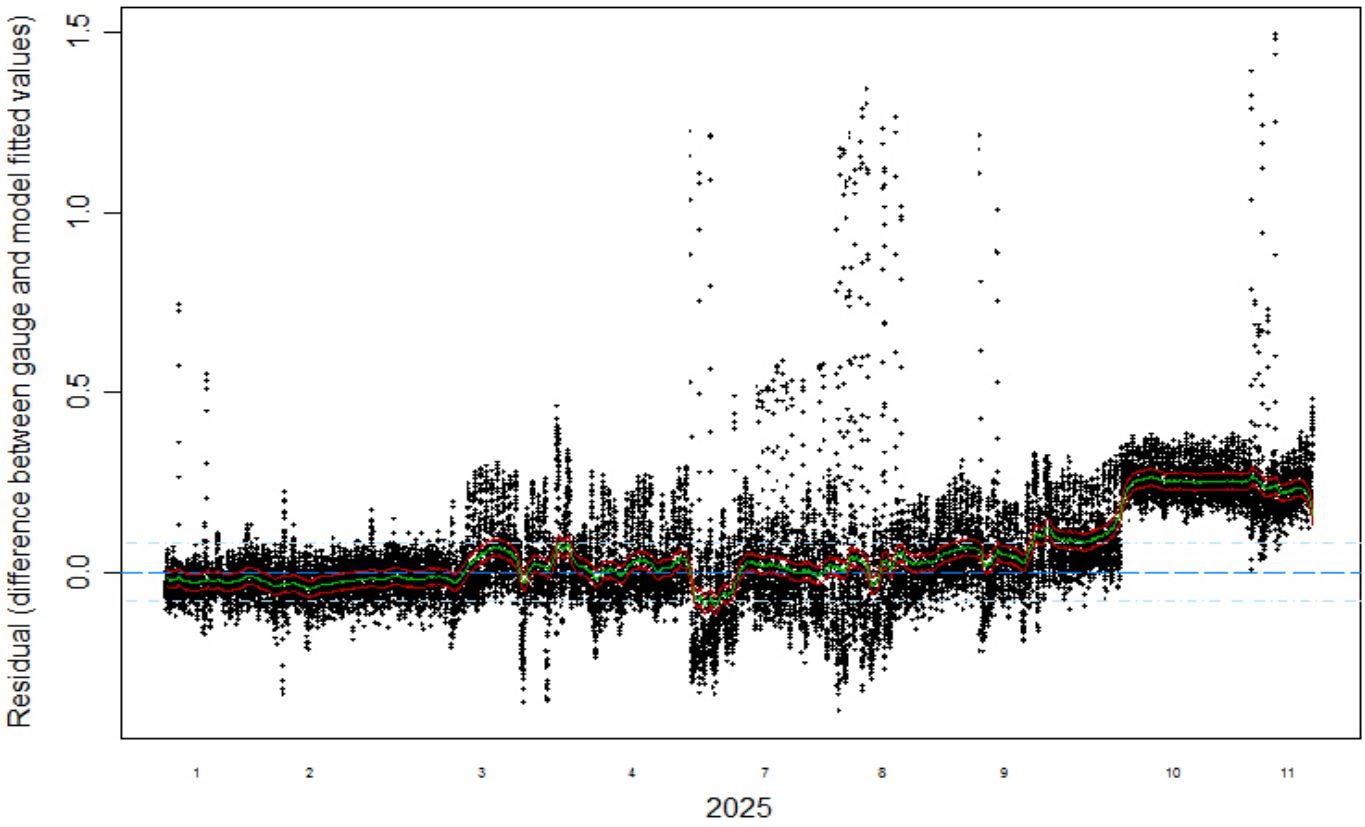
Gauge filename: R:\Wwdih\Palms\Sts\Malabar\Swagman/G802051SQ.txt (19030 observations)
Model filename: R:\Wwdih\Palms\Sts\Malabar\Swagman/M802051SQ.txt (32925 observations)

18837 observations in matched dataset.

Criteria Values for assessing model performance
==========

	all observations	specified region (1.464534 to 1.881126)	
MSE	0.0266		0.0143
R abs	0.54	0.22	
R squared	0.83	0.57	
R sq (lag gauge)	0.82		
R sq (lag model)	0.83		
adjusted R sq	0.7	0.11	
adjusted R sq (lag gauge)	0.69		
adjusted R sq (lag model)	0.71		

Residual plots for FlowRate at Site 802051



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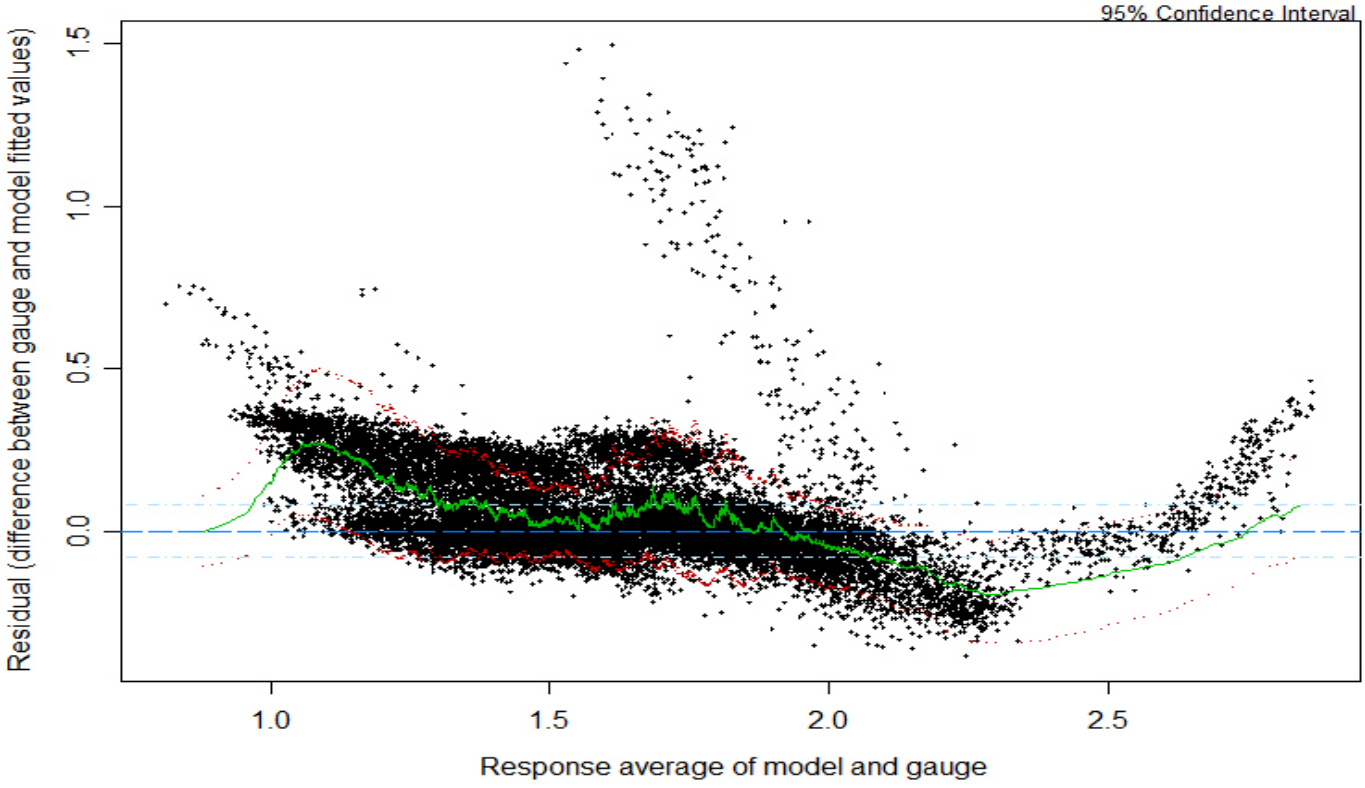

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Level Report for Station 802063

Gauge filename: R:\Wwdih\Palms\Sts\Malabar\Swagman/G802063L.txt (19030 observations)
Model filename: R:\Wwdih\Palms\Sts\Malabar\Swagman/M802063L.txt (32925 observations)

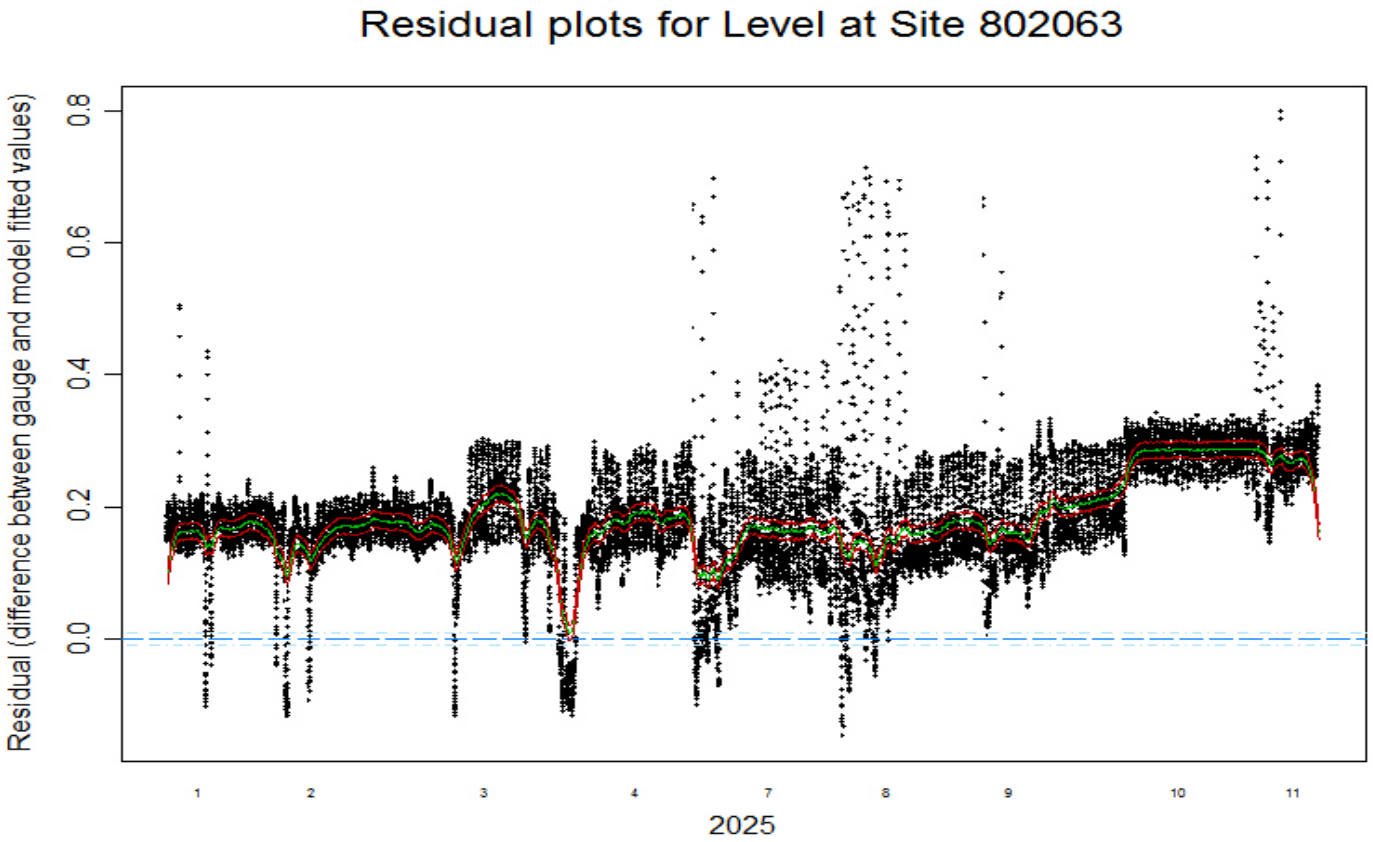
18837 observations in matched dataset.

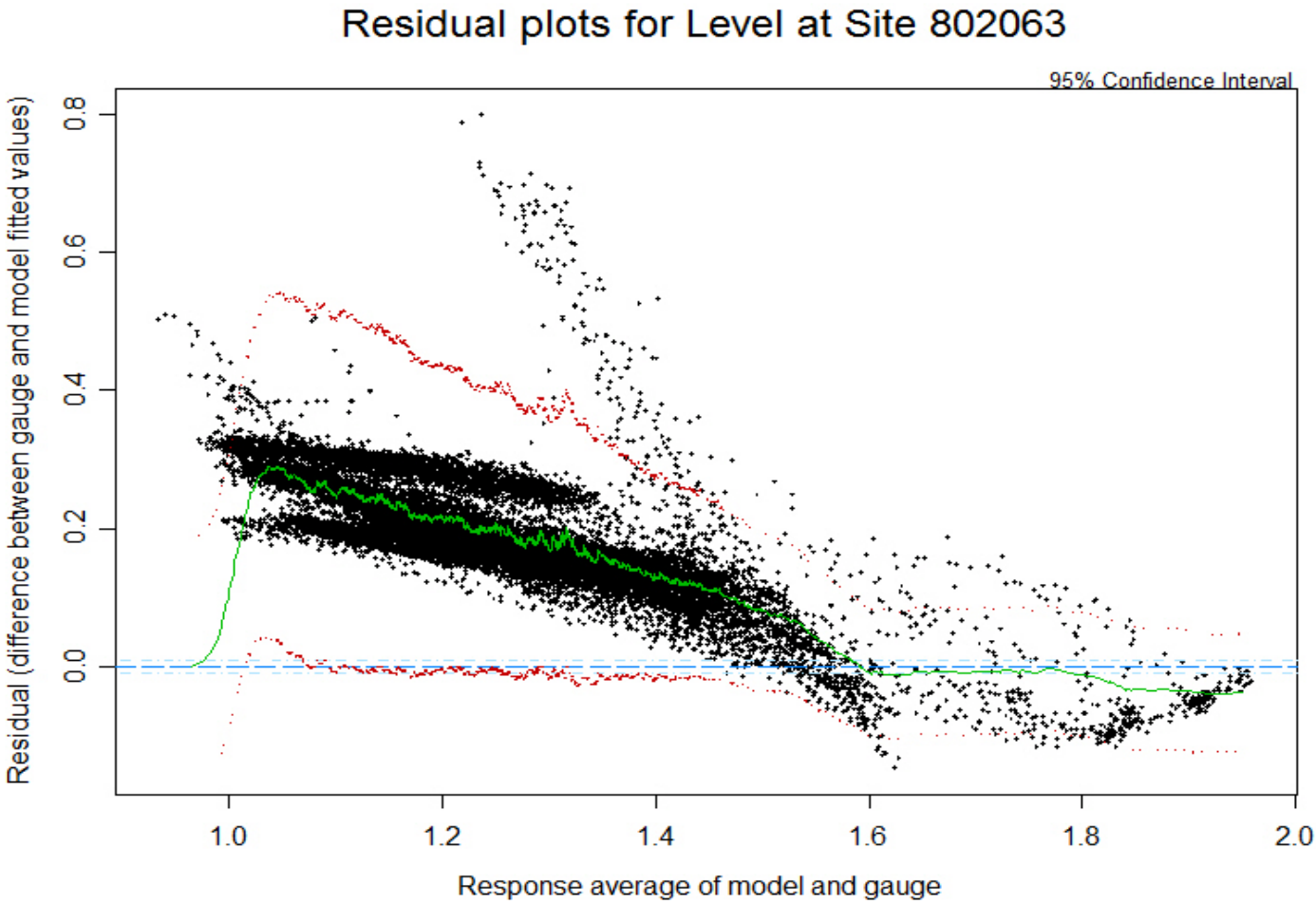
Criteria Values for assessing model performance

	all observations	specified region (1.2921 to 1.45)
MSE	0.0408	0.0357
R abs	-0.99	-3.68
R squared	0.88	0.64
R sq (lag gauge)	0.88	
R sq (lag model)	0.87	
adjusted R sq	-1.76	-16.74
adjusted R sq (lag gauge)	-1.75	
adjusted R sq (lag model)	-1.78	

Probability of weir overflow events

Event	Probability
Measured > 1.7	0.023
Fitted > 1.7	0.023
Both Measured & Fitted > 1.7	0.021
Measured > 1.7 given Fitted > 1.7	0.913





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Level Report for Station 802064

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Model filename: R:\Wwdih\Palms\Sts\Malabar\Swagman/M802064L.txt (32925 observations)

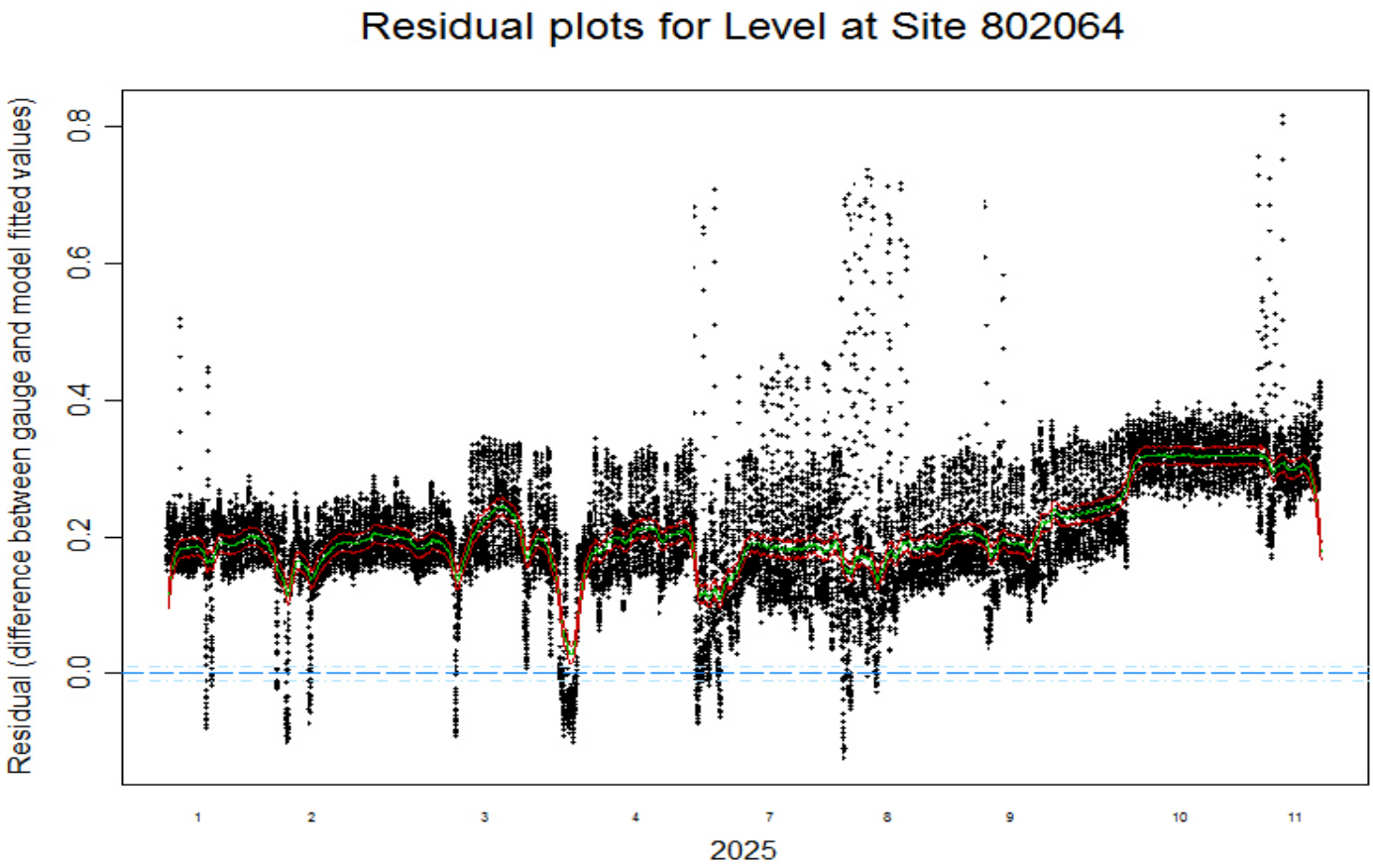
18837 observations in matched dataset.

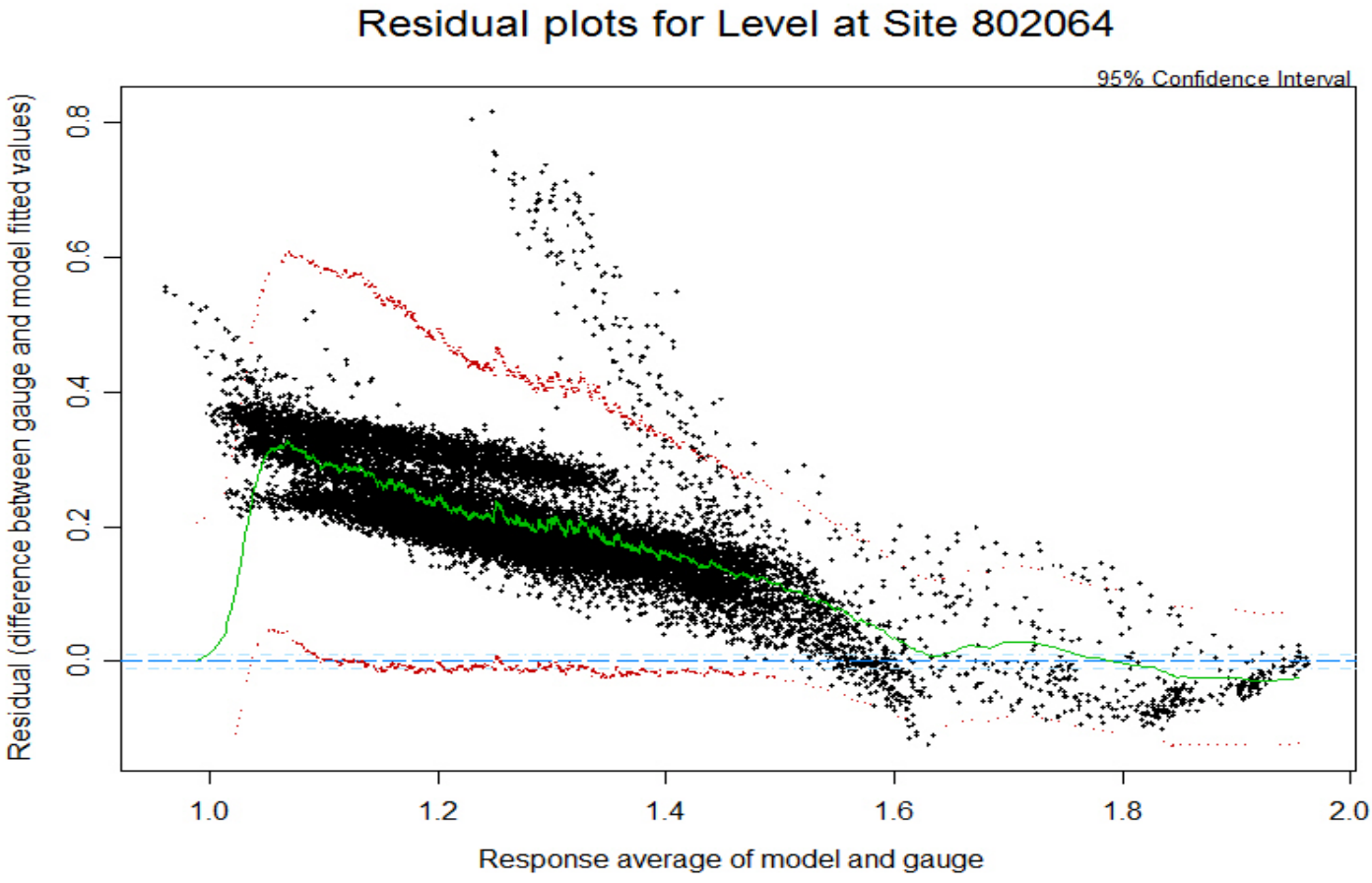
Criteria Values for assessing model performance
==========

	all observations	specified region (1.3139 to 1.4671)
MSE	0.051	0.0451
R abs	-1.34	-4.36
R squared	0.85	0.56
R sq (lag gauge)	0.86	
R sq (lag model)	0.84	
adjusted R sq	-2.76	-22.54
adjusted R sq (lag gauge)	-2.74	
adjusted R sq (lag model)	-2.77	

Probability of weir overflow events
==========

Event	Probability
Measured > 1.7	0.024
Fitted > 1.7	0.023
Both Measured & Fitted > 1.7	0.022
Measured > 1.7 given Fitted > 1.7	0.957





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Level Report for Station 802065

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Model filename: R:\Wwdih\Palms\Sts\Malabar\Swagman/M802065L.txt (32925 observations)

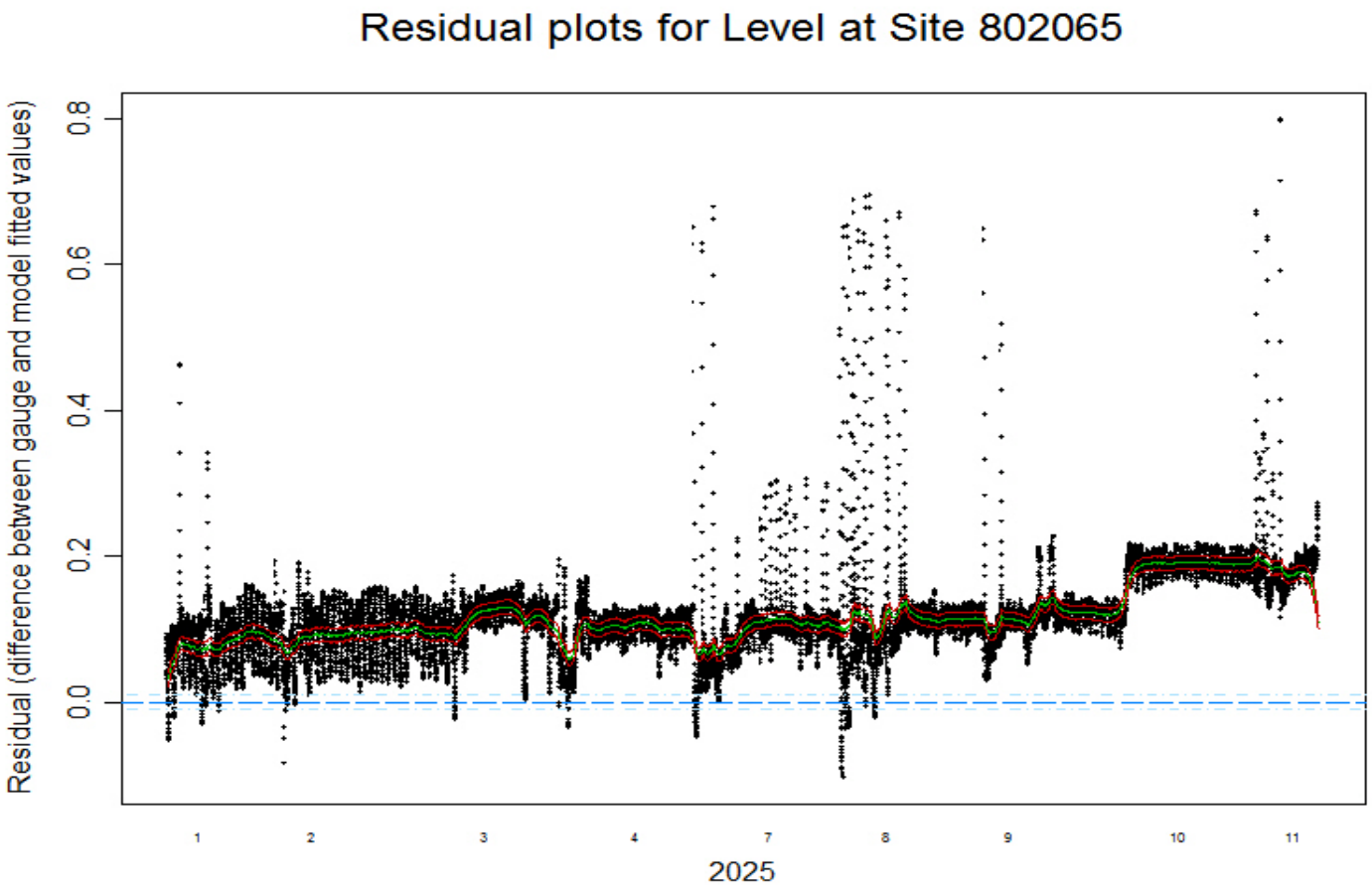
18837 observations in matched dataset.

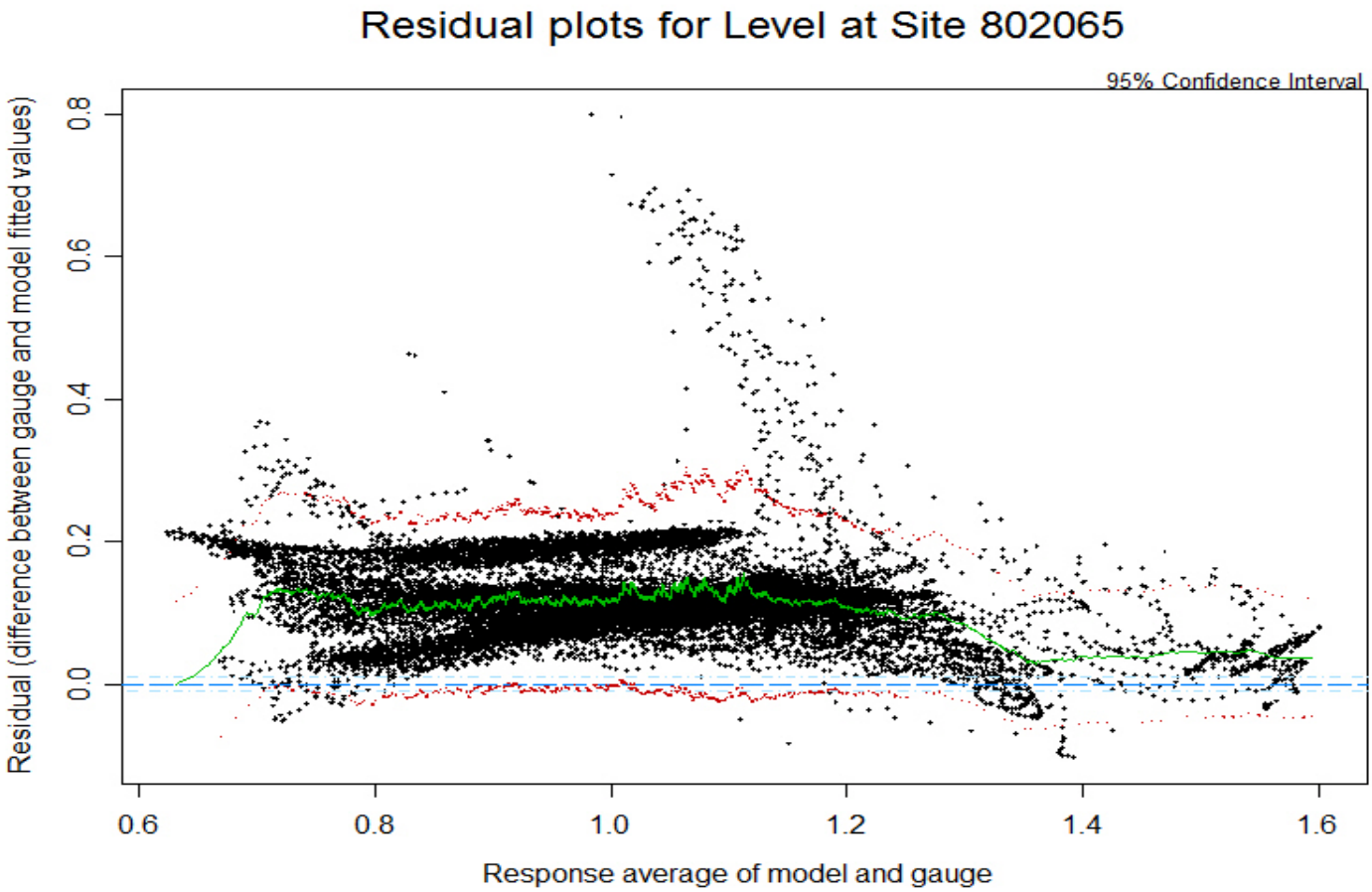
Criteria Values for assessing model performance

	all observations	specified region (0.9973 to 1.20318)
MSE	0.0173	0.0166
R abs	0.05	-1.45
R squared	0.87	0.67
R sq (lag gauge)	0.87	
R sq (lag model)	0.87	
adjusted R sq	0.30	-3.89
adjusted R sq (lag gauge)	0.30	
adjusted R sq (lag model)	0.30	

Probability of weir overflow events

Event	Probability
Measured > 1.3	0.928
Fitted > 1.3	0.264
Both Measured & Fitted > 1.3	0.264
Measured > 1.3 given Fitted > 1.3	1.000





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Level Report for Station 802310

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Model filename: R:\Wwdih\Palms\Sts\Malabar\Swagman/M802310L.txt (32925 observations)

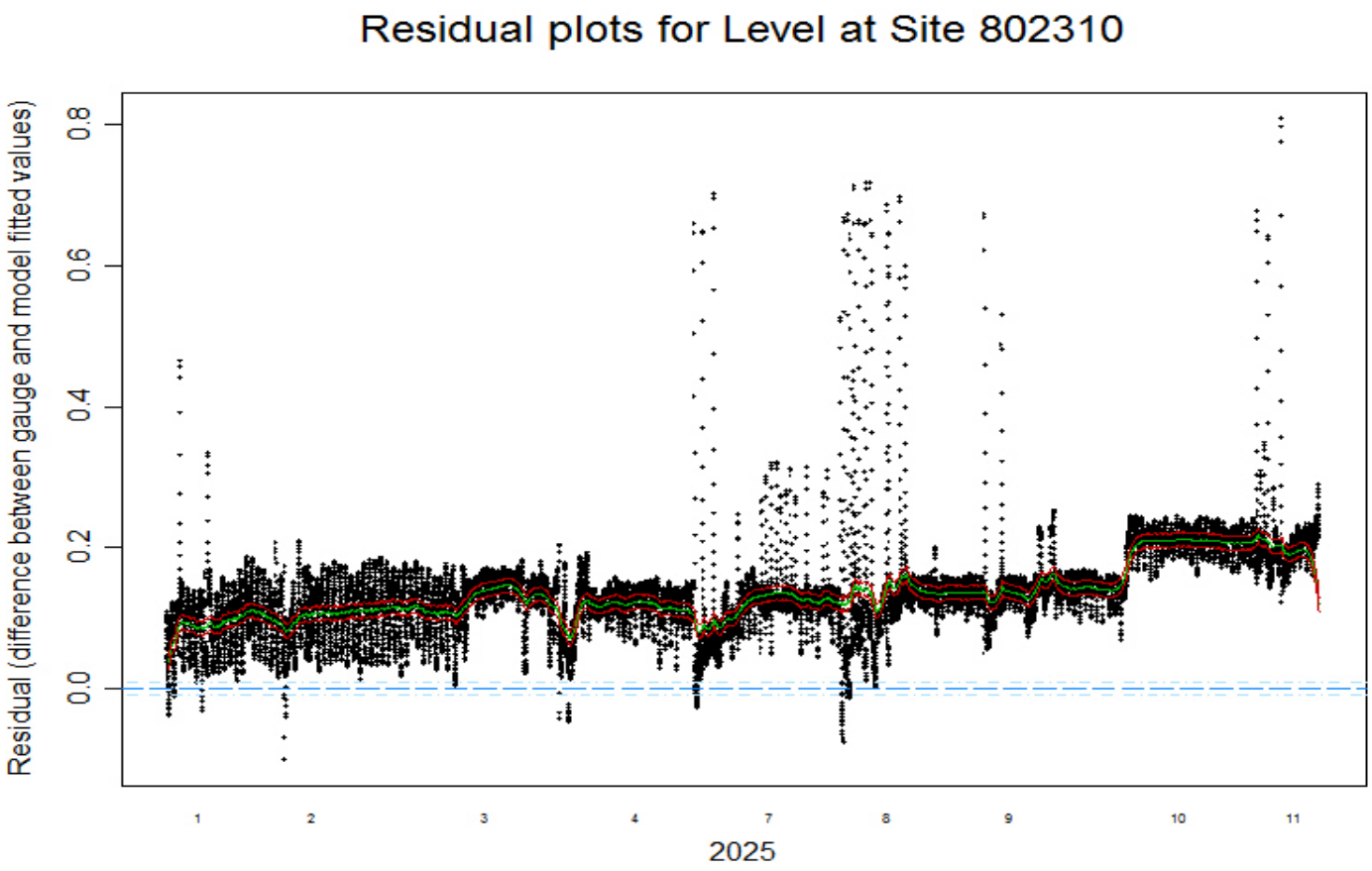
18837 observations in matched dataset.

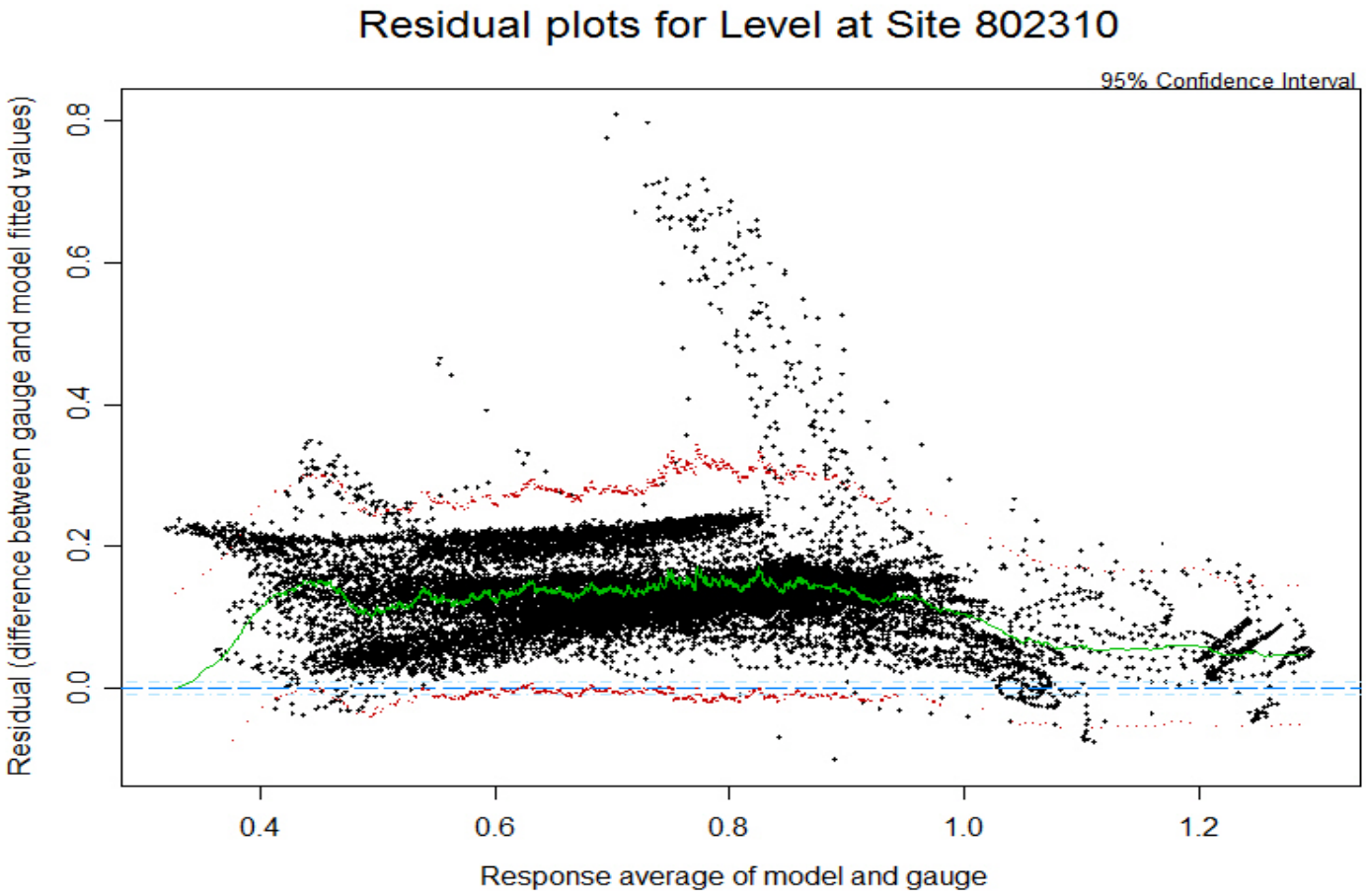
Criteria Values for assessing model performance
==========

	all observations	specified region (0.7199 to 0.9302)
MSE	0.0221	0.0219
R abs	-0.06	-1.77
R squared	0.86	0.65
R sq (lag gauge)	0.85	
R sq (lag model)	0.86	
adjusted R sq	0.14	-5.14
adjusted R sq (lag gauge)	0.13	
adjusted R sq (lag model)	0.14	

Probability of weir overflow events
==========

Event	Probability
Measured > 1.2	0.023
Fitted > 1.2	0.013
Both Measured & Fitted > 1.2	0.013
Measured > 1.2 given Fitted > 1.2	1.000





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Attachment 5 PRP 101.1 and 101.2

Sydney WATER

Pollution Reduction Program

PRP 101.1 System Model Performance Indicators

September 2000

DOCUMENT STATUS

This report was prepared in response to the Pollution Reduction Program No 101.1 attached to Sydney Water's 27 STS licences. During the preparation of this document, peer reviews were carried out at draft and final report stages. This is the final version of the report.

Any comments regarding this report should be directed to Mr Greg Barr on:
Phone 9350 5141
E-mail Greg.Barr@sydneywater.com.au

ENDORSED BY:

..... Date:
Warwick Eyles
Program Manager
Overflow Abatement Program.

CONTROL COPY SHEET

PRP 101.1

CONTROLLED COPY:				
Issue No.	Date	Description	Prepared By (Author)	Reviewed by:
1	29/9/00	Completed Document	Steven Linforth	Andrew Kasmarik

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Glossary

1. INTRODUCTION

1.1 Background

Sydney Water is developing computer models of its sewerage networks in order to prepare plans for the improvement of the system. These models will be used to predict the performance of the network under both wet and dry conditions. The EPA wish to be assured that the predictions of these models compares favourably with measured data in the sewerage system .In this way the EPA can be confident that the model predictions are realistic and can be used for compliance monitoring.

The licence conditions for this pollution reduction program are as follows:

101.1.1

The licensee must develop a set of performance indicators for comparing the predictions of the hydraulic sewer system model with the data from the reticulation sewer gauge network operated by or on behalf of the licensee. The licensee must develop a set of performance acceptance criteria for the hydraulic sewer system model based on the indicators. The indicators and criteria must be applicable to all of the sewage treatment system specific models developed in 101.3 and the range of sewer flows in these systems.

101.1.2.

By 30 September the licensee must supply to the EPA a written report detailing:
(a) the proposed indicators and criteria developed under 101.1.1 for approval by the EPA
(b) the rationale explaining why these indicators or criteria are proposed.

101.1.3

Following approval by the EPA the licensee must apply the indicators and criteria to the models in accordance with 101.2 to 101.6

This report has been prepared to comply with the requirements of PRP101.1 System Model Performance Indicators for the 27 sewage treatment system (STS) licences indicated in **Table 1.1**.

Table 1.1: Sewage Treatment System Names and Licence Numbers

LICENCE NUMBER	LICENCE SYSTEM
1775	Bellambi
1712	Blackheath
1688	Bondi
1725	Castle Hill
1728	Cronulla
1407	Glenbrook
750	Hornsby Heights
2269	Kiama
1716	Mount Victoria
190	North Richmond
378	Northern Suburbs
1409	Penrith
1696	Port Kembla
1724	Quakers Hill
1726	Richmond
1796	Riverstone
2392	Round Corner
4965	Rouse Hill
211	Shellharbour
372	Malabar/Southern Suburbs
1729	St Marys
1778	Warragamba
1784	Warriewood
1675	West Camden
1695	West Hornsby
1963	Winmalee
218	Wollongong

1.2 Planning history and description of the system

Sydney Water is a major provider of water and wastewater services in Australia. It is a state-owned corporation belonging to the people of NSW. Sydney Water has three equally important principle objectives, which are to be a successful business and to protect the environment and public health. These objectives are expressed in terms of environmental, public health and commercial goals in response to customer commitments, which are defined in the Water Board Corporatisation Act (1994) and Operating Licence.

WaterPlan 21 is Sydney Water's vision for long term, ecologically sustainable wastewater management across the Sydney, Blue Mountains and Illawarra region. The plan resulted from a process of investigations commenced in the late 1980s devoted towards improving the sewerage systems performance. The plan includes $1.6 billion to overhaul Sydney Water's sewerage systems and ultimately eliminate an

average of 80-90 per cent of wet weather overflow events across the area. In addition, Sydney Water proposes to spend $0.4 billion on linked dry weather overflow abatement programs. The total cost of the overflow abatement program (OAP) for wet and dry weather improvements is therefore $2 billion. These cost will be spread over the next twenty years. Any pricing impacts of this program will need an IPART determination.

Sydney Water provides sewerage services to almost three and three quarter million people and maintains 28 sewerage systems, consisting of some 22,000 kilometres of sewer. The current performance and Sydney Water long-term objectives for 2021 for the systems are shown in table 1.2.

Table 1.2: Current and Sydney Water 2021 objectives for sewerage system performance

	Dry weather		Wet Weather	
Overflow type	**Current**	**future**	**current**	**Future**
leakage (exfiltration)	suspected to cause failure of swimming / boating criteria in some receiving waters	will not cause dry weather failure of swimming / boating criteria	not applicable	not applicable
wet weather treatment	not applicable	not applicable	H/N STP's disinfection fails in small storms. Minor ocean plant *1 – beach fail faecal coliform criteria in storms	STP discharge will not cause failure of water quality criteria
directed overflows	50 individual discharges per year *2	less than 15 discharges per year	up to 200 events per 10 years 350,000 ML per 10 years	80-90 per cent average reduction in events per 10 years across Sydney
uncontrolled overflows	internal surcharge – 140 reported events per year 96 per cent of customers no external overflows	less than 10 internal surcharges per year due to sydney water capacity individual customers experiencing choke related overflows (2 per 6 months or 3 in 2 years) guarantee no repeat for two years	200 known areas *3	• no internal surcharges due to sydney water capacity • fix to known surcharge areas 96 per cent of customers no external overflows
odours	20 individual assets cause repeat odour complaints	less that 3 verified odour events per year for an individual asset (eg vent shaft, sps)	unknown	Frequency of odour events no greater that wet weather overflow frequency

*1 minor ocean plants include; Warriewood, Cronulla and Illawarra STP's
*2 predominantly SPS failures
*3 total unkown as not all wet weather events reported

The planning conducted to date has provided a firm base for implementation of the OAP. Whilst Sydney Water does not recommend any major changes to the proposal as defined in the overflows EISs, a number of other initiatives and events have occurred which could constrain or impact upon the delivery of the OAP. These include; the NSW Governments Waterways Package, amendments to the Clean Waters Regulation and Classification of Waterways, the enactment of the *Protection of the Environment Operations Act 1997* and the overflow abatement strategy proposed by the EPA.

It is recognised that additional detailed planning and environmental impact assessment will be undertaken as part of the OAP and through pollution reduction programs set by the EPA. Refinement of the detail of overflow abatement options will be via a continuous and adaptive process and will reflect current and future community concerns.

The EPA issued the Sewage Treatment System licences to Sydney Water on 26th May 2000. The STS licences set the EPA priorities and timetable for overflow abatement. The Pollution Reduction Programs (PRPs) set out the specific works and activities required to achieve that outcome. The documents produced here, form part of the suite of reports required to be prepared as part of the PRP's. Completion of the PRP's will not achieve the long-term objectives of Sydney Water.

1.3 Sydney Water monitoring framework

The monitoring undertaken by Sydney Water can be defined in two broad areas:

A. Monitoring programmes to measure system performance; and
B. Monitoring programmes to measure impacts of overflows on the environment.

These can further be subdivided into the following monitoring types:

1. **Routine** monitoring - undertaken as part of system performance monitoring;
2. **Project** monitoring – undertaken for specific works/ planning projects;
3. **R&D** monitoring – undertaken as specific research and development projects.

The existing routine monitoring that is undertaken as part of business performance reporting, can be broadly categorised into this framework as shown in Table 1.3.

Table 1.3 – Existing monitoring

Monitoring Type	Performance monitoring	Impact monitoring
Routine monitoring	• Chokes/100km Sydney-wide • No. customers affected by surcharges • Repeat chokes • Odour complaints • Representative overflow reporting • Incident monitoring –dry weather discharges to waterways	• Components of existing Environmental Impact Monitoring Program (under revision) • Incident management response monitoring
***Project monitoring**	• Interim I/E gauging programme • Sewer flow gauging	• Interim I/E water quality monitoring; • Ecological & human health risk assessment monitoring of overflows; • Northside storage tunnel pilot study monitoring; • Dry weather point source sewage detection
R&D monitoring		• Clean Waterways Program water quality stormwater and receiving water monitoring for model development

* = Some project monitoring occurs periodically over a cycle of several years.

It is proposed that the routine monitoring outlined above, would form the basis of the licence monitoring requirements. Project and R&D monitoring would continue to be applied on a needs basis.

1.4 Sydney Water modelling framework

The models used to develop the overflow abatement proposals in the Environmental Impact Statements (EISs), were deemed to be appropriate for strategic planning purposes, by two independent criteria review committees. Their continued use for the purposes of performance monitoring and licence compliance would however, require them to be further developed. The EPA has accordingly, developed a PRP to satisfy that outcome.

As part of the analysis conducted in the overflows EISs, it became apparent that system output performance measures were the most appropriate means of assessing the performance and indicating the impacts of the sewerage systems. It was clear, that modelling environmental condition, resulting from overflows was not appropriate, because of the confounding influence of external factors such as stormwater. Benefits delivered by overflow abatement would be masked by these external factors.

Sydney Water therefore proposes that output performance monitoring, measured by sewer system models and other non-modelled attributes, would form the basis of licence reporting. Environmental water quality models would continue to be used for setting strategic direction and assessing overall environmental condition but not for

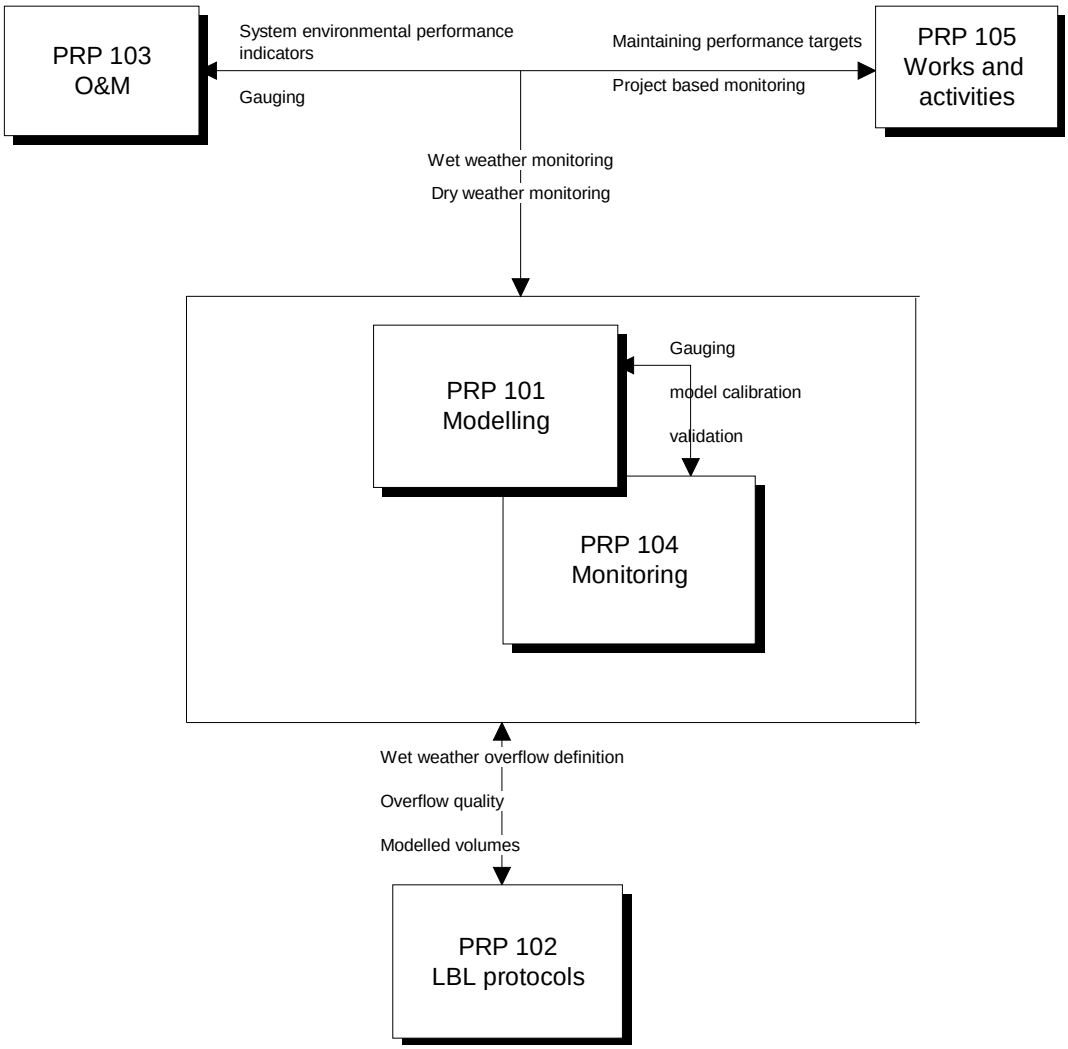
compliance monitoring. Whilst both suites of models would be improved over time, the majority of the effort would be devoted to improving the system models.

Performance monitoring will be measured by the sewerage system models, in terms of overflow frequency and/or volume. The system models will be upgraded by a process of developing a quality system, performance targets and re-calibration protocols. These processes will be reported as part of licence compliance reporting.

1.5 Achieving the long term objectives

The STS licences set the EPA priorities and timetable for overflow abatement. The PRPs reduction programs set out the specific works and activities required to achieve that outcome. Figure 1.1 indicates the interrelationships between the PRPs as a guide, to enable the process and interrelationships to be understood.

Figure 1.1: Pollution Reduction Program interrelationships



2. SELECTION OF PERFORMANCE INDICATORS

2.1 Introduction

The ideal performance indicator should be relevant to the problem at hand, easy to measure in the field and a direct output from the trunk sewerage system models. If a number of performance indicators are needed then they should be independent of each other. Comparison of the indicator between field measurement and model prediction will then provide a direct measure of the ability of the model to reproduce the behaviour measured in the field .It is the primary objective of these indicators that they be good measures of the ability of the model to reproduce field measurements.

The selected indicators must therefore be measurable in the field and a direct output of the model. As the system behaviour changes over time and with weather conditions the chosen indicators must be able to reflect this change.

As there are difficulties and costs associated in measuring system behaviour and in the modelling of this behaviour, the indicators must be chosen with an understanding of these difficulties. The following sections outline what is currently possible with respect to measurement of the behaviour of the system in the field and with respect to modelling this behaviour. The selection of appropriate indicators then follows.

2.2 Measurement Process

In order to establish performance indicators, it is first necessary to have an appreciation of the measurement process .The measurement process has a number of steps and at each step there will be some error added to the overall result. These errors provide a fundamental limit to the accuracy to which the subsequent computer models can be developed.

Sydney Water has installed monitoring devices to measure the depth and velocity of flow in sewers at critical points of interest. This data has been collected for a number of reasons including defining the hydraulic performance at a point in the network, for calibration of computer based hydraulic models, control of the system and for licensing purposes. As the need for sewer monitoring varies so does the need for a monitoring station at a given location. Over time this has meant that many points have been monitored over a particular period and then closed down.

When calibrating a model it is necessary to have contemporaneous data so that model parameters can be adjusted at the subcatchment level to account for variation in the local conditions. This requires a dedicated monitoring program in the local catchment for a period of at least three months in order to capture enough rainfall events to enable the computer model to be calibrated satisfactorily.

The primary data, which is collected, is sewage depth and velocity at predefined time intervals. The cross sectional properties of the pipe or channel are also needed to be measured in order to calculate sewage flow. The velocity of sewage in a pipe varies across the cross section from zero at the boundary to a maximum value somewhere near the top of the flowing surface. The location of this maxima change with increasing flow and in particular when the water surface hits the top of pipe and the pipe becomes pressurised.

Typically the device used to measure water level is an ultrasonic level sensor, located at the top of the pipe. The signal from the sensor is transmitted by a transducer, reflected off the surface of the flow and received by an adjacent transducer. Four ultrasonic transducers housed within the sensor are capable of both transmitting and receiving signals. The transducers operate in pairs, such that they have a maximum combination of twelve pairs. The depth of flow is calculated by subtracting the echoed range (of the sensors transmitted signal) from the pipe diameter.

The main variable, which must be compensated for, is the temperature of the air in which the signal travels. An internal temperature detection system is housed within the transmitter and is used to determine the temperature of the air in the sewer .The variations in temperature and resulting variation in travel time are then used in the computation of the final value.

When the height of the water exceeds the bottom surface of the transducer the ultrasonic device is out of range. In this circumstance another device is required to measure the water pressure. The pressure sensors measure the depth of sewage in the maintenance hole by comparing atmospheric pressure to the water height pressure at each sensor.

A digital doppler velocity sensor monitors velocity. The velocity sensor is mounted on the bottom of the pipe and emits an ultrasonic beam transmitted at a known frequency through the flow. Some of the transmitted energy is reflected by moving particles in the flow and received by the sensor at a different frequency .The Doppler principle states that the energy reflecting from a moving object will experience a shift in frequency proportional to the speed of the moving object. In the case of sewage flow, the object could be any suspended moving particle, air bubble or mass of organic matter.

A spectrum of reflected energy from all objects is gathered by the monitor and analysed to calculate the peak velocity of flow within the measured area. A relationship must then be made between the mean velocity and peak velocity. This requires techniques in the field to make this relationship. For the gauges installed on

behalf of Sydney Water the methods used were velocity profile, peak velocity search and dye dilution techniques.

Monitoring was also undertaken on a number of pump stations. There were three common arrangements depending on the pump type and existing monitoring devices. For fixed speed stations the pump on /off status was recorded. For dual speed pumps, the high and low speeds were recorded and flow rates adjusted as for fixed speed pumps. Some pump stations have existing flow measurement devices and these were recorded.

Rainfall is the other major hydrological variable that is recorded. Sydney Water monitors rainfall at 140 locations. Tipping bucket pluviometers are used which log rainfall events of 0.5mm with a resolution of 2 minutes.

All data is stored electronically on the HYDSYS database.

2.3 Trunk sewerage system model

In order to establish performance indicators it is also necessary to have an appreciation of the hydraulic modelling process. The hydraulic modelling process has a number of steps and at each step there will be some error added to the overall result. These errors influence the accuracy of the computer models ultimately developed.

Sydney Water is developing computerised models of each of the sewerage networks and these are known as Trunk Sewerage System Models. The process of building a model requires extensive effort and resources. The key elements of the model building process are described in this section.

The catchment to which the sewerage system is connected must first be defined. Sydney Water has defined all boundaries to the sewer network and these are stored in a geographic information system (GIS). The physical characteristics of the pipe network must then be established. The primary source of this data is stored on the Hydra-Smallword GIS and needs to be simplified for the purposes of modelling. This simplification is necessary to allow the numerical computations of the system to be undertaken within practical timeframes.

The primary simplifications are to extend the model pipe network up to a point that has a permanent flow gauge. Within the defined pipe network the number of maintenance holes simulated is reduced to that necessary to define major junctions, flow measurement points, overflow points, changes in pipe diameter or pipe slope. The headloss from intermediate maintenance holes are lumped into the pipe friction. During this phase of the model building process it is often necessary to supplement the data from prime sources with other information such as cover levels, invert levels, pipe sizes, pipe shapes, missing overflow pipes and carefully check the connectivity of the system.

Where simplification has been undertaken it is necessary to ensure that surcharge volumes are maintained in the model and these will be allocated to the remaining maintenance holes. A pipe roughness must then be allocated to each pipe length and this is initially done on the basis of the pipe material. The type of maintenance hole cover must also be allocated.

The next major step is to assign dry weather flows to each maintenance hole. This is done by using census data to allocate populations to each maintenance hole. Commercial and Industrial users are allocated separately where appropriate. Sydney Water has developed routines, which allow water usage data to be used as a check against measured flow data. Sydney Water has also developed a range of flow profiles, which can be used to model diurnal flow patterns.

Following establishment of the dry weather behaviour the wet weather behaviour must be determined. A hydrological model known as MOUSENAM is used to predict inflows to the sewer system in response to rainfall in the catchment. It is a lumped rainfall runoff model, which classifies the wet weather flow hydrograph into a fast response component (FRC) and a slow response component (SRC). FRC is a direct consequence of rainfall and is not influenced by previous hydrologic conditions. SRC responds only slowly to rainfall and is highly dependent on previous hydrologic conditions. MOUSENAM is a combination of Surface Runoff Model, which generates FRC, and NAM model that generates SRC. Each model has a set of parameters that must be defined for each subcatchment.

Having defined the physical characteristics of the pipe network and the wet and dry weather inflows it is then possible to undertake a hydraulic simulation of the network. Sydney Water has chosen to use the MOUSE model for this purpose. The MOUSE model has been widely used around the world and has been endorsed by the Criteria Review Committee. It can simulate backwater effects, flow reversal, surcharging maintenance holes, free surface and pressurised flow, tidal outfalls and storage basins. The model computes discharge and water level at alternating points throughout the network at each time step. To ensure the equation produces stable, physically realistic results it is necessary to run the model at time steps typically less than 60 seconds.

The output from the model is water level and flow at each point in the network at each time step. As the model is run over long time periods it is therefore possible to generate a time series of water level and flow at each point in the network.

2.4 Recommended Performance Indicators

A key test of a performance indicator is the relevance of the indicator to the problem at hand. The problem in this case is to compare the predictions of the hydraulic model with data measured from the sewerage system network. From the discussion above it is apparent that the two variables that can be compared between measured and modelled data are water level above invert of pipe and flow in the sewer.

Of these two the primary indicator is water level above pipe invert as it has the advantage that it can be directly measured in the field and is explicitly computed in the trunk sewerage system model. Instruments are available which allow the recording and logging of this data over time. These data can be directly compared with the predictions of the trunk sewerage system models. This indicator meets the ideal criteria for a performance indicator as it is simple to measure and it is applicable for both low and high flows.

The second recommended performance indicator is flow in the sewer data. Flow in the sewer is a direct output of the model. It has a disadvantage in that it is not as easily measured as water level as it must be derived from water level, velocity and pipe cross sectional information. It is a fundamental indicator however as it is ultimately flow which influences the behaviour of the network. It also has the advantage that is a direct output from the trunk sewerage system model.

A model that can accurately predict flow and level can then be used for a wide range of purposes. Of specific interest to EPA and Sydney Water is the ability of the model to predict overflows. Overflows occur when the water level at the overflow structure exceeds the overflow level. The water level predicted at each timestep can be compared to the overflow level to see if an overflow is predicted. The probability of the model predicting an overflow incidence when the measurements indicate an overflow is the third recommended indicator and will be called the overflow incidence index.

The three recommended system performance indicators are therefore water level in the sewer, flow in the sewer and overflow incidence index. These three indicators will allow the performance of the trunk sewerage sewer system model to be assessed.

3. SELECTION OF ACCEPTANCE CRITERIA

3.1 Introduction

For each performance indicator there must be tests that can be applied to determine whether the predicted performance matches the measured performance. These tests need to be statistical in nature to ensure they are independent of the person undertaking the test. The criteria associated with these tests must be rigorous enough to ensure the model does reproduce measured behaviour. The criteria must also take into accounts the errors associated with measurement and modelling. These errors provide a fundamental limit to the degree models can reproduce measured behaviour.

These issues were raised by the Criteria Review Committee (CRC) meeting of October 1997. It was a finding of this Committee that Sydney Water should engage an independent consultant to develop statistical techniques to review model accuracy. Following this meeting Sydney Water engaged the CSIRO division of Mathematical and Information Sciences to undertake this work. The subsequent section detail the methodology recommended by CSIRO.

Following this review Sydney Water held another CRC in November 1999. This committee found that the,“adopted methodology appears to overcome inherent interpretation and understanding difficulties of more conventional statistical methods which rely on using standard deviations to determine whether differences between measured and model results are significant at adopted probability levels. The residual plots produced by the statistics package are simple to read and interpret although the underlying statistics may not be understood.”

The November 1999 CRC also considered that “the chosen statistics are statistically robust because they address both bias (temporal and magnitude) and variability due to the measurement and modelling processes“. This CRC recommended those additional non-statistical “common sense” criteria are also necessary to determine whether a model should be accepted or rejected. This is required because it is possible to have a statistically significant difference even though the difference is physically insignificant.

The November 1999 CRC also recommended that gauge contractors be encouraged to gauge over the full in-pipe flow range to improve gauge accuracy at higher flows. They also recommended that a protocol be developed to ensure gauge accuracy.

Another CRC was held in June 2000 and this found that the tool developed to assess model accuracy by CSIRO known as SWAGMAN “considers that all relevant sources

of error are included in SWAGMAN. The package analyses bias (temporal and magnitude) and variability caused by measurement and modelling."

The following sections provide an outline of the principles of uncertainty in both measurement and modelling used to develop the methodology for determining appropriate acceptance criteria.

3.2 Uncertainty due to measurement error

Measurement uncertainty is caused by the process of measurement not replicating the true value the model is attempting to fit. Measurement uncertainty is the sum of the following uncertainties:

- Sampling errors: an example of this is sampling at a location in the sewer that does not give the maximum level of flow in the sewer. Alternatively, velocity meters could be positioned in the sewer in a manner where the true average velocity is not measured.
- Gauge errors: Gauge measurements are biased, for example, they give measured values consistently below the true value.
- Measurement errors of model input: Gauge rainfall not being measured accurately and the centroid rainfall is not the true centroid of the local catchment relating to a gauged value of level and flow rate

The errors generated in this process provide a fundamental limit to how well the model can explain the variability in the measured data. Monitoring for water level and velocity is now undertaken in accordance with specific limits for gauge bias and variability. The objective of these gauge accuracy tests is to ensure that these monitors have a within site error of less than 10%. These procedures together with those associated with measurement of rainfall are expected to limit the measurement error to less than 15%. This being the case it follows that the model can only explain the remaining 85% of the variation that is not due to measurement uncertainty

3.3 Uncertainty due to modeling

The process of building a model was described earlier and incorporates many steps. At each stage in this process errors are introduced. This is an unavoidable consequence of the modelling process. The skill of the modeller is in making the right simplifications and judgements to minimise the generation of errors.

Typically within the model building process considerable effort must go into defining the pipe network both in terms of its connectivity and its shape and level. As discussed in the earlier section on model building the network must be simplified in order to reduce the time for numerical computation. Significant effort is also required to adequately represent the dry and wet weather flow behaviour.

In making these decisions it is necessary to compare measured data to modelled output. As there is uncertainty on measured data the modeller must use judgement on how closely to match each measured point with the model output.

In addition to the errors associated with the input to the model there are many other forms that modelling uncertainty can take including:

- An important explanatory variable is not included in the model;
- The model has not made full use of the information in an explanatory variable ;
- Measurement uncertainty in the response variable makes it difficult to model measured responses;
- Measurement uncertainty in the explanatory variable makes parameter estimation less certain;
- Wrong parameterisation /functional form used to model the data;
- The process used to estimate the parameters of the model is sub-optimal and produces biased estimates;
- The calibration data generally does not cover the full range of response values the model is to predict and therefore model fit is poor in the range of values not represented in the calibration.

If we are able to define the contribution to prediction uncertainty caused by measurement error as say 15%, then we know that the best a modeller can do is fit the remaining 85% variation that is not due to measurement uncertainty. If for example the fitted model describes 80% of the variation in a validation sample, then the modelling uncertainty is defined in terms of its expected value if there were no measurement errors or sampling errors. That is in this example it would be estimated as

$$100\%-80\%/(100\%-15\%) \times 100\%= 5.8\%$$

Therefore we would say that measurement uncertainty is 15% and modelling uncertainty is 5.8%. With current technology and methods the aim is to ensure that model uncertainty is less than 15%.

3.4 Statistical techniques for comparing model predictions to data

There are two aspects that must be considered when comparing measured data to model output. The first is the bias the model exhibits in predicting the measured data. Biased values are encountered when the model on average over-predicts or under-predicts measured values. For example if the model predicts the level of sewage in the pipe to be on average 0.5m higher than it should be we would say there is a bias of 0.5m.

The second aspect, which relates to the lack of fit between the model and measured data, is the variation in prediction values from its on average prediction value. This is generally known as the prediction variance. If the same set of model inputs are

repeated on several occasions then the measured value for the response is not usually reproduced on every one of these occasions. This happens because of both model and measured uncertainties. If for a large number of these repeated events the average response equals the model fitted value, then we say the model is unbiased for this set of inputs. The amount these response values vary from the model fitted value is an estimate of the predictive variance for this set of input values. The overall lack-of-fit of a model is the sum of the bias value squared and the predictive variance, and this is often called the mean squared error of prediction (MSEP).

The MSEP is a good measure for comparing models for the same response but as it is not scale invariant it is often difficult to judge whether a good fit has been achieved. Other criteria which are independent of scale include Pearson's Correlation Coefficient (r) and variations of this criteria known as adjusted R-squared and Rabs.

Pearson's correlation coefficient is widely used in practice and this coefficient measure the correlation between measured and model fitted data. A coefficient of one (1) would indicate a perfect association between the measured and modelled data. It is however possible to obtain a coefficient of one without the values of measured and modelled data being equal and this is due to bias.

A robust measure of the goodness of fit would therefore be scale invariant and consider bias and correlation. Two measures which do this are adjusted R-squared and Rabs. These measures test whether the model fitted values are better than fitting using only the mean response value .The first method known as adjusted R-squared uses squared deviations from measured values as a criterion of fit .The second measure uses absolute deviations from measured values as a criterion of fit and is known as Rabs. The second method is less sensitive to outliers than the first.

In both of these methods the maximum value which can be achieved is one (1) and that is when the model fitted data are identical to the measured values. If the criteria are negative it indicates that the model fitted values are worse than using the mean value to predict the response value. These indicators provide a valuable insight into the goodness of fit.

3.5 Recommended performance acceptance criteria

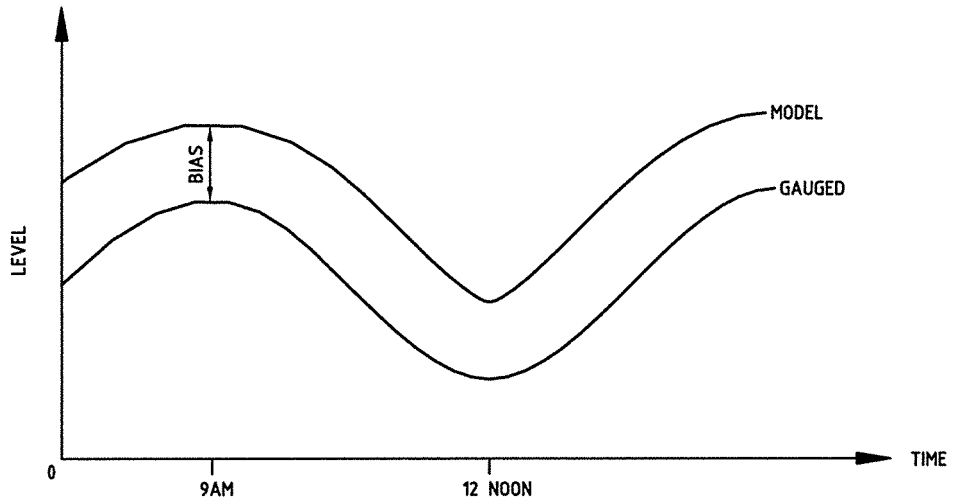
3.5.1 Introduction

From the work undertaken by CSIRO it is clear that a good model must be unbiased and must have an acceptable level of fit. Bias can take two forms and they are defined as temporal bias and magnitude bias. Temporal bias assesses how well the model reproduces the measured data in terms of closeness in time. Magnitude bias assesses how well the model reproduces the measured value as the magnitude of the performance indicator (level or flow) increases. The lack of fit can be measured by several statistics but as bias reduces to zero all of these values converge to Pearson's correlation coefficient.

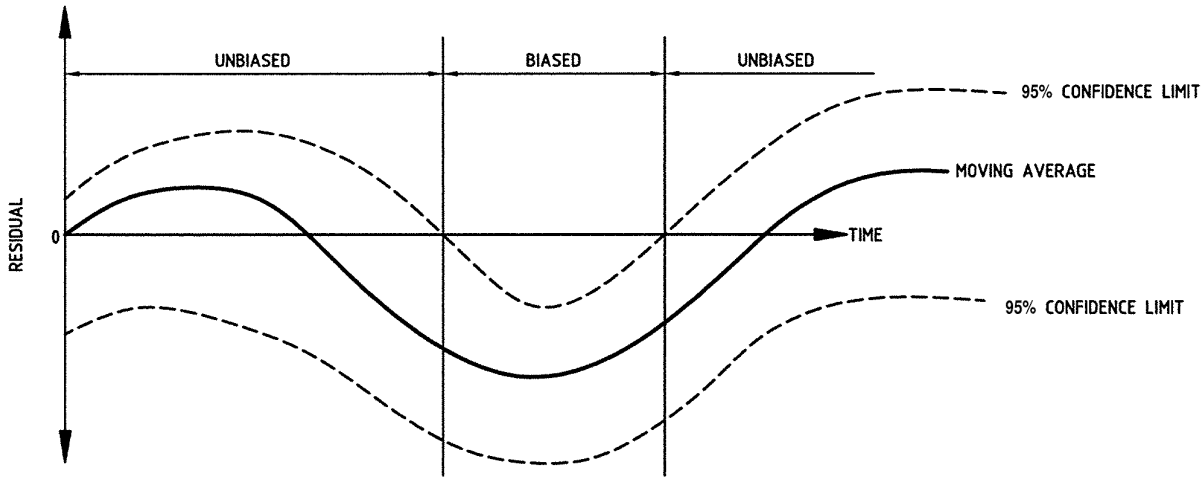
Acceptance criteria dealing with each of these aspects is discussed below. They have been developed based on the CSIRO methodology and enhanced with the contribution of the CRC and recent experience of Sydney Water in the application of these tests.

3.5.2 Temporal bias

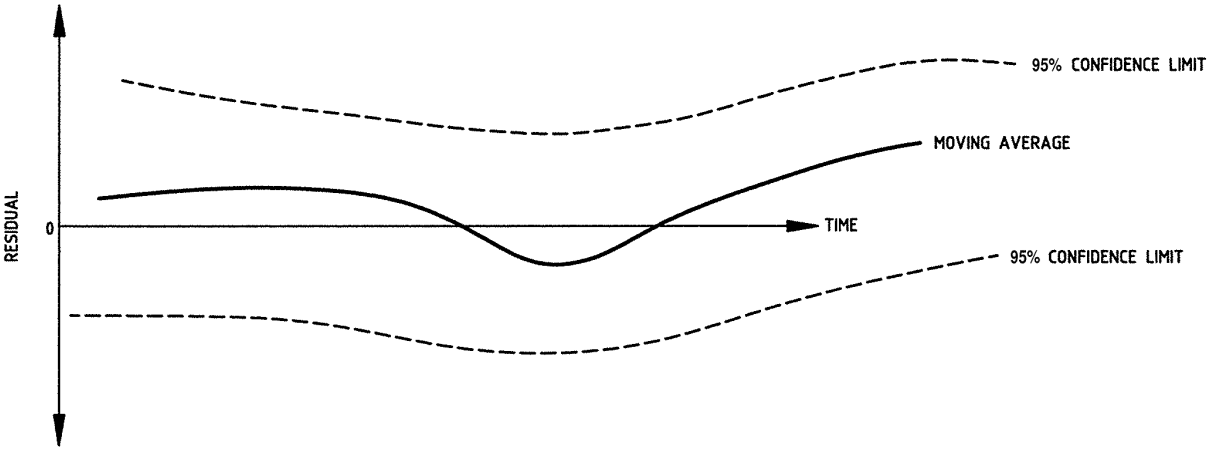
This is the bias that occurs at a particular time of the year, possibly because of seasonal variations, or biases in particular years because its weather differed from previous years. The figure below shows a plot of sewer level over time. There are two lines, one from a model output and the other from a sewer gauge. A similar distance separates them and this seems relatively constant with time. This difference is the local temporal bias.



This can be detected visually by subtracting the model values for the performance indicator from the measured value and plotting this against time. The difference between measured and modelled values is known as the residual. Over time the residual value should not differ significantly on average from zero. Any significant or consistent trend of the local mean away from the zero value will indicate a local bias in model predictions. The following figure shows an example where the model is unbiased initially and then becomes biased for a period of time. Following this period the model becomes unbiased again. This model would need re-calibration to correct for this bias.



For each gauge it will be required to compare measured data to model values in a pairwise comparison of the difference between gauge and model values. This residual should be plotted in a time series with a non-linear smoother passing through the local average residual value. Residuals should not differ significantly on average from zero, therefore the location mean of the residuals should be a random walk about the residual equal to zero line .The 95% confidence intervals of the local means should span the zero residual line. Where the 95% confidence intervals cross the zero residual line it should do this an equal amount of times above and below the line. The figure below shows the results from a model that is temporally unbiased.

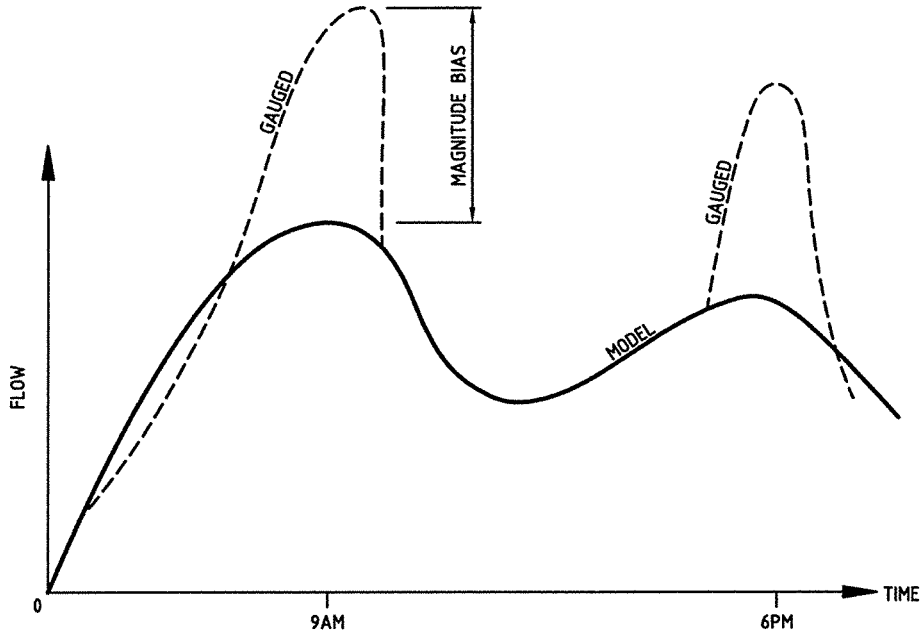


In rare circumstances the 95% confidence intervals may be very close as there is good agreement between the measured and modelled value but they do not span the zero line. In these cases if the arithmetic mean of the residual is less than 10mm for level or 5% of the average dry weather flow in the case of flow the model will have been considered to have passed the temporal bias test. This conditional criterion allows for the CRC comments of November 1999 where they noted that a statistically significant bias could occur which were physically insignificant.

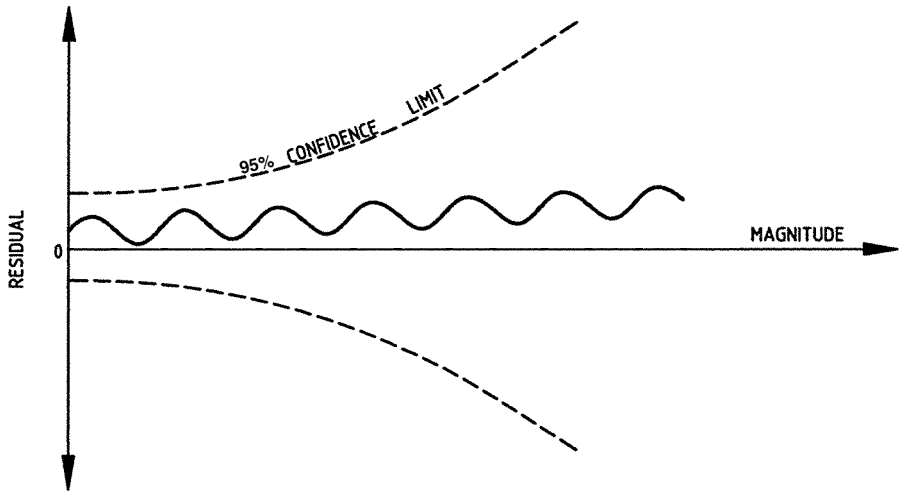
A recommended performance acceptance criterion therefore is that the model should have no significant temporal bias subject to a test for physical significance. This will provide assurance that the model ability to predict measured behaviour is unbiased over time.

3.5.3 Magnitude bias

This is the model bias that may have occurred because the model is calibrated for a specific range of magnitudes .For example, we may calibrate the model for dry weather periods that experience low flow and find that the model does not predict high flows well. This problem has been identified in earlier CRC meetings and the new gauging contracts encourage the contractors to take field measurements over the full range of flows. The figure below shows a plot of sewer flow over time. The results of a model output and a gauged flow are plotted on the figure. The plot indicates that the model under-predicts flow at high flow rates but is a good predictor at low flow rates. This model has a magnitude bias and this is indicated on the figure.



Magnitude bias is tested by plotting the difference between the gauge and model fitted value (residual) versus the average of these fitted and gauged values. In all cases the local mean of the residual should not trend significantly away from zero as model and gauge values increase. This is determined by plotting the 95 % confidence intervals of the local mean and ensuring that they span the zero residual line. Where the 95% confidence interval crosses the zero residual line it should do this an equal amount of times above and below the line. The output from a model that has no significant magnitude bias is shown in the following figure.



A recommended performance acceptance criterion therefore is that the model has no significant magnitude bias subject to a test for physical significance This will ensure that the model provides unbiased predictions over the range of flows and levels experienced.

3.5.4 Goodness of fit

Three Goodness of fit criteria has been described and they are Pearson's correlation coefficient r^2, **Adj.Rsq** and **Rabs**. These should be calculated over the period of record for both flow and level. These criteria assess the model ability to predict the variation observed in the measured data. As the models must be calibrated to ensure they have no significant temporal or magnitude bias it is proposed to use the conventional Pearsons correlation coefficient as the key measure .

From earlier work it was indicated that measurement error could explain up to 15 % of the observed variation and modelling variation could also explain up to 15% of the variation. As these errors are independent it is not appropriate to simply add the errors but from work undertaken in the last year it is likely that they combine to explain on average 20 to 25% of the observed variation. The model should explain the remaining 75% to 80% of the observed variation.

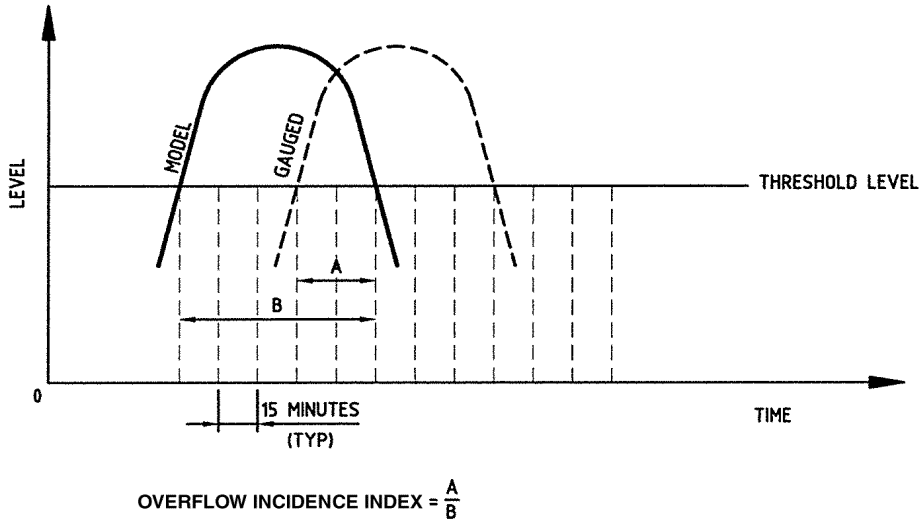
The minimum acceptable Pearson's correlation coefficient is 0.75.

3.5.5 Overflow incidence index

Of broad interest to both the EPA and Sydney Water is the ability of the model to predict the incidence of overflow when an overflow has been measured. Overflows occur when the sewer level in the pipe exceeds the threshold level for overflows. This test is therefore a subset of the more general test for water level explained previously.

In this test a minimum of three months of data must be compared to model predictions on a 15-minute time increment. This time series should include at least three periods of time where significant overflows occurred (as a guide measured

overflows should have occurred for at least 5 hours). The number of times the model predicts an overflow when the measurements have indicated an overflow should be noted. This number should be divided by the number of times the model predicted that the overflow level exceeded the threshold level over the entire time series. This comparison is shown for a single event on the figure below.



OVERFLOW INCIDENCE INDEX = $\frac{A}{B}$

With current technology and the uncertainties associated with modelling and measurement, the model should be able to achieve an overflow incidence index exceeding 75%. The model shown above therefore would not be considered acceptable and would require re-calibration.

The minimum acceptable overflow incidence index is 75%.

3.5.6 Time for EPA approval of indicators and acceptance criteria

PRP101.3 requires that Sydney Water must complete re-calibration of all models by 31 October 2001. In order to achieve this tight time frame it will be necessary for EPA to approve the recommended indicators and their associated acceptance criterion by 31 October 2000.

4. REFERENCES

CSIRO Mathematical and Information Sciences, “Validation Process for fitted Models of LEVEL and FLOWRATE in Sewer Pipelines”, Report Number CMIS D16/112 June 1998

Sydney Water, System Services, Distribution “Statistical Validation of Sewerage Systems Northern Suburbs Ocean Outfall Sewage System”, October 1998

Sydney Water, Overflow Abatement Program, Criteria Review Committee (CRC) for Sydney Harbour Wastewater Planning Project (SHWPP) and OACIS for OAP, Nielsen Environmental Pty Ltd November 1999

Sydney Water, Overflow Abatement Program, Criteria Review Committee (CRC) No 2 for Sydney Harbour Wastewater Planning Project (SHWPP) and OACIS for OAP, Nielsen Environmental Pty Ltd June 2000

GLOSSARY

Response Variable	The measure we want the model to predict well. An example is level of the flow in sewer pipelines. This variable is denoted by y_t for the response measured at time t.
Explanatory Variable	These are the model-input variables. Their information is fed into the model to give the predicted response values. For example, rainfall at a catchment centroid is an explanatory variable used to predict level in sewer pipelines. The I'th measured input is denoted by x_{Iit} for measurements made at time *t*
Residual	The difference between measured values of a response variable and their corresponding model fitted value.

Sydney WATER

Pollution Reduction Program

PRP 101.2 Generic Model Re-calibration Protocol

September 2000

DOCUMENT STATUS

This report was prepared in response to the Pollution Reduction Program No 101.2 attached to Sydney Water's 27 STS licences. During the preparation of this document, peer reviews were carried out at draft and final report stages. This is the final version of the report.

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CONTROL COPY SHEET

PRP 101.2

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Issue No.	Date	Description	Prepared By (Author)	Reviewed by:
1	29/9/00	Completed Document	Steve Linforth	Andrew Kasmarik

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1. INTRODUCTION

1.1 Background

Sydney Water is developing computer models of its sewerage network in order to prepare plans for the improvement of the system. These models are used to predict the performance of the network under both wet and dry conditions. These models are calibrated to data collected over a specific period of time. These models will be used by Sydney Water to estimate overflows for licencing purposes into the future. It is therefore necessary to check the models from time to time to ensure they continue to produce reliable estimates. This PRP describes the process used to check the models and the process required to re-calibrate the models if these checks show that the model no longer meets acceptance criteria.

The specific licence conditions for this PRP are as follows

101.2.1

The licensee must develop a generic Model Re-Calibration Protocol for the ongoing re-calibration of the hydraulic sewer system models that, at a minimum, addresses the following issues:

(a) development of a set of re-calibration triggers based on factors such as time , completion of works or trends in model output:

(b) The nature and level of information required to carry out the re-calibration. The assessment of data requirements must address , at a minimum , the following concepts :

- (i) minimum acceptable time series rainfall data length;
- (ii) minimum number of rainfall events;
- (iii) minimum range of rainfall event size ;

that must be collected to enable the model to be re-calibrated.

(c) development of a generic re-calibration methodology that can be used to recalibrate the models and demonstrate that the subsequently re-calibrated models continue to meet the approved performance acceptance criteria;

(d) options and actions to be undertaken if the subsequently re-calibrated model is unable to achieve the approved performance acceptance criteria;

(e) the need to update monitoring requirements as a result of the re-calibration; and

(f) a process for convening an independent Criteria Review Committee for the purposes of PRP101.4.

101.2.2 The licensee must submit for approval to the EPA a copy of the written Model Re-Calibration Protocol by no later than 30 September 2000

This report has been prepared to comply with the requirements of PRP101.2 Generic Model Re-Calibration Protocol for the 27 STS licences indicated in **Table 1.1**.

Table 1.1: Sewage Treatment System Names and Licence Numbers

LICENCE NUMBER	LICENCE SYSTEM
1775	Bellambi
1712	Blackheath
1688	Bondi
1725	Castle Hill
1728	Cronulla
1407	Glenbrook
750	Hornsby Heights
2269	Kiama
1716	Mount Victoria
190	North Richmond
378	Northern Suburbs
1409	Penrith
1696	Port Kembla
1724	Quakers Hill
1726	Richmond
1796	Riverstone
2392	Round Corner
4965	Rouse Hill
211	Shellharbour
372	Malabar/Southern Suburbs
1729	St Marys
1778	Warragamba
1784	Warriewood
1675	West Camden
1695	West Hornsby
1963	Winmalee
218	Wollongong

1.2 Planning History and description of the system

Sydney Water is a major provider of water and wastewater services in Australia. It is a state-owned corporation belonging to the people of NSW. Sydney Water has three equally important principle objectives, which are to be successful business and to protect the environment and public health. These objectives are expressed in terms of environmental, public health and commercial goals in response to customer commitments, which are defined in the Water Board Corporatisation Act (1994) and Operating Licence.

WaterPlan 21 is Sydney Water's vision for long term, ecologically sustainable wastewater management across the Sydney, Blue Mountains and Illawarra region. The plan resulted from a process of investigations commenced in the late 1980's devoted towards improving the sewerage systems performance. The plan includes $1.6 billion to overhaul Sydney Water's sewerage systems and ultimately eliminate an average of 80-90 per cent of wet weather overflow events across the area. In addition, Sydney Water proposes to spend $0.4 billion on linked dry weather overflow abatement programmes. The total cost of the overflow abatement program (OAP) for wet and dry weather improvements is therefore $2 billion. These costs will be spread over the next twenty years. Any pricing impacts of this program will need an IPART determination.

Sydney Water provides sewerage services to almost three and three quarter million people and maintains 28 sewerage systems, consisting of some 22,000 kilometres of sewer. The current performance and Sydney Water long-term objectives for 2021 for the systems are shown in table 1.2.

Table 1.2: Current and Sydney Water 2021 objectives for sewerage system performance

	Dry weather		**Wet Weather**	
	Current	**future**	**current**	**Future**
leakage (exfiltration)	suspected to cause failure of swimming / boating criteria in some receiving waters	will not cause dry weather failure of swimming / boating criteria	not applicable	not applicable
wet weather treatment	not applicable	not applicable	H/N STP's disinfection fails in small storms. Minor ocean plant *1 – beaches fail faecal coliform criteria in storms	STP discharge will not cause failure of water quality criteria
directed overflows	50 individual discharges per year *2	less than 15 discharges per year	up to 200 events per 10 years 350,000 ML per 10 years	80-90 per cent average reduction in events per 10 years across Sydney
uncontrolled overflows	internal surcharge – 140 reported events per year 96 per cent of customers no external overflows	less than 10 internal surcharges per year due to sydney water capacity individual customers experiencing choke related overflows (2 per 6 months or 3 in 2 years) guarantee no repeat for two years	200 known areas *3	• no internal surcharges due to sydney water capacity • fix to known surcharge areas 96 per cent of customers no external overflows
odours	20 individual assets cause repeat odour complaints	less that 3 verified odour events per year for an individual asset (eg vent shaft, sps)	unknown	Frequency of odour events no greater that wet weather overflow frequency

*1 minor ocean plants include; Warriewood, Cronulla and Illawarra STP's
*2 predominantly SPS failures
*3 total unkown as not all wet weather events reported

The planning conducted to date has provided a firm base for implementation of the OAP. Whilst Sydney Water does not recommend any major changes to the proposal as defined in the Environmental Impact Statements (EISs) for Licencing Sewerage Overflows, a number of other initiatives and events have occurred which could constrain or impact upon the delivery of the OAP. These include; the NSW

Governments Waterways Package, amendments to the Clean Waters Regulation and Classification of Waterways, the enactment of the *Protection of the Environment Operations Act 1997* and the overflow abatement strategy proposed by the EPA.

It is recognised that additional detailed planning and environmental impact assessment will be undertaken as part of the OAP and through pollution reduction programs set by the EPA. Refinement of the detail of overflow abatement options will be via a continuous and adaptive process and will reflect current and future community concerns.

The EPA issued the Sewage Treatment System licences to Sydney Water on 26th May 2000. The STS licences set the EPA priorities and timetable for overflow abatement. The Pollution Reduction Programs (PRPs) set out the specific works and activities required to achieve that outcome. The documents produced here, form part of the suite of reports required to be prepared as part of the PRP's. Completion of the PRP's will not achieve the long term objectives of Sydney Water.

1.3 Sydney Water monitoring framework

The monitoring undertaken by Sydney Water can be defined in two broad areas:

A. Monitoring programmes to measure system performance; and
B. Monitoring programmes to measure impacts of overflows on the environment.

These can further be subdivided into the following monitoring types:

1. **Routine** monitoring - undertaken as part of system performance monitoring;
2. **Project** monitoring – undertaken for specific works/ planning projects;
3. **R&D** monitoring – undertaken as specific research and development projects.

The existing routine monitoring that is undertaken as part of business performance reporting, can be broadly categorised into this framework as shown in Table 1.3.

Table 1.3 – Existing monitoring

Monitoring Type	Performance monitoring	Impact monitoring
Routine monitoring	• Chokes/100km Sydney-wide • No. customers affected by surcharges • Repeat chokes • Odour complaints • Representative overflow reporting • Incident monitoring –dry weather discharges to waterways	• Components of existing Environmental Impact Monitoring Program (under revision) • Incident management response monitoring
***Project monitoring**	• Interim I/E gauging programme • Sewer flow gauging	• Interim I/E water quality monitoring; • Ecological & human health risk assessment monitoring of overflows; • Northside storage tunnel pilot study monitoring; • Dry weather point source sewage detection
R&D monitoring		• Clean Waterways Program stormwater and receiving water quality monitoring for model development

* = some project monitoring occurs periodically over a cycle of several years.

It is proposed that the routine monitoring outlined above, would form the basis of the licence monitoring requirements. Project and R&D monitoring would continue to be applied on a needs basis.

1.4 Sydney Water modelling framework

The models used to develop the overflow abatement proposals in the EISs, were deemed to be appropriate for strategic planning purposes, by two independent criteria review committees. Their continued use for the purposes of performance monitoring and licence compliance would however, require them to be further developed. The EPA has accordingly, developed a PRP to satisfy that outcome.

As part of the analysis conducted in the overflows EISs, it became apparent that system output performance measures were the most appropriate means of assessing the performance and indicating the impacts of the sewerage systems. It was clear, that modelling environmental condition, resulting from overflows was not appropriate, because of the confounding influence of external factors such as stormwater. Benefits delivered by overflow abatement would be masked by these external factors.

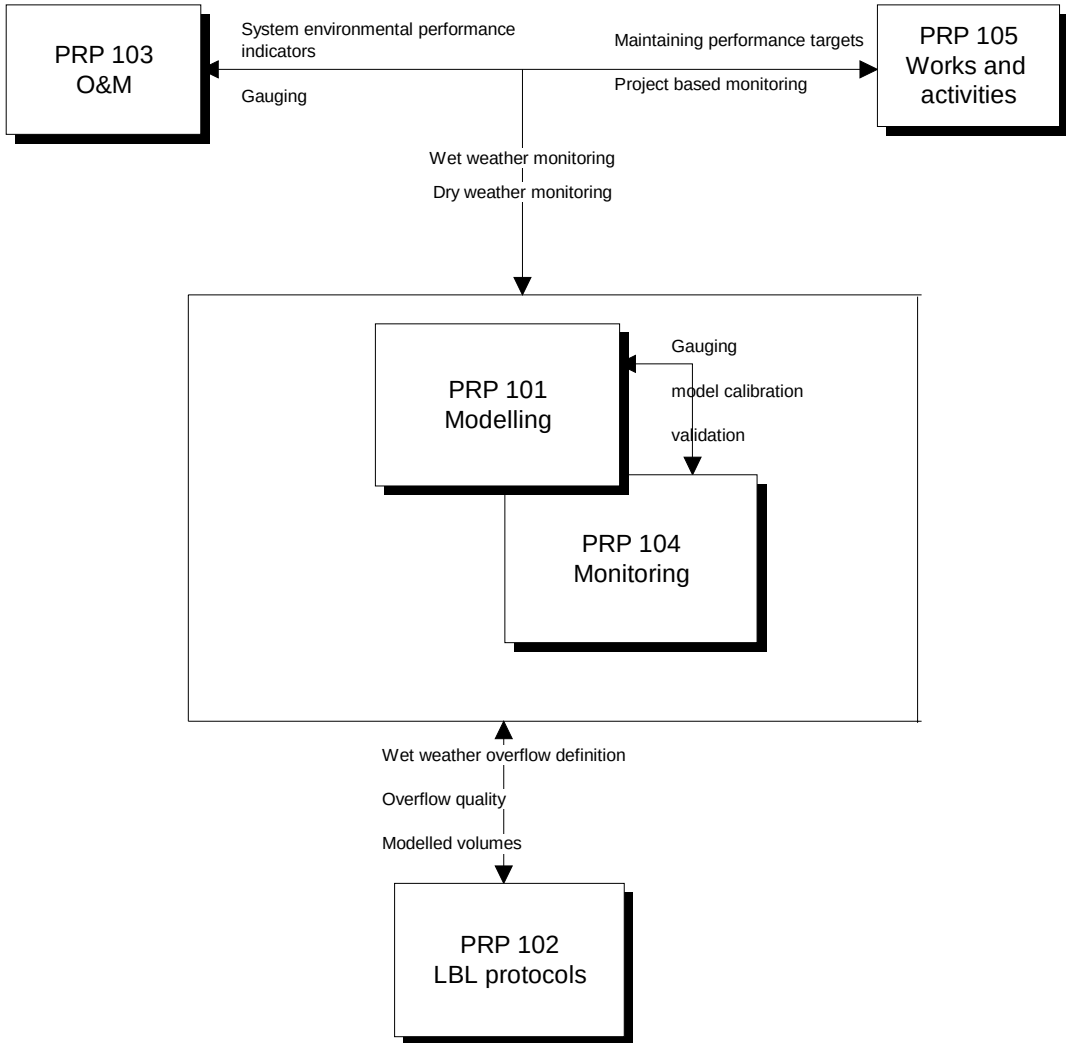
Sydney Water therefore proposes that output performance monitoring, measured by sewer system models and other non-modelled attributes, would form the basis of licence reporting. Environmental water quality models would continue to be used for setting strategic direction and assessing overall environmental condition but not for compliance monitoring. Whilst both suites of models would be improved over time, the majority of the effort would be devoted to improving the system models.

Performance monitoring will be measured by the sewerage system models, in terms of overflow frequency and/or volume. The system models will be upgraded by a process of developing a quality system, performance targets and re-calibration protocols. These processes will be reported as part of licence compliance reporting.

1.5 Achieving the long term objectives

The STS licences set the EPA priorities and timetable for overflow abatement. The PRPs set out the specific works and activities required to achieve that outcome. Figure 1.1 indicates the interrelationships between the PRPs as a guide, to enable the process and interrelationships to be understood.

Figure 1.1: PRP interrelationships



2. TRUNK SEWERAGE SYSTEM MODEL

2.1 Introduction

For each of the sewerage systems Sydney Water operates, a MOUSE model is being developed. These models are known as Trunk Sewerage System Models and they model the major pipes of the network down to a diameter of 300mm. Typically this results in the catchment being divided up into subareas in a range from 10 Ha to 800Ha. Within this network the major hydraulic features such as pump stations, overflow points and pipelines are incorporated.

This chapter discusses the processes that are being used to develop these models and the criteria that are being used to decide when a model is calibrated and verified. These models and the way they have been developed are introduced as background to this PRP. This PRP describes the triggers that will cause Sydney Water to re-calibrate the model, the data requirements for re-calibration and the protocols for recalibration in the following chapters.

2.2 Model building process

The catchment to which the sewerage system is connected must first be defined. Sydney Water has defined all boundaries to the sewer network and these are stored in a geographic information system (GIS). The physical characteristics of the pipe network must then be established. The primary source of this data is stored on the Hydra-Smallword GIS and needs to be simplified for the purposes of modelling. This simplification is necessary to allow the numerical computations of the system to be undertaken within practical timeframes.

The primary simplifications are to extend the model pipe network up to a point that has a permanent flow gauge. Within the defined pipe network the number of maintenance holes simulated is reduced to that necessary to define major junctions, flow measurement points, overflow points, changes in pipe diameter or pipe slope .The headloss from intermediate maintenance holes are lumped into the pipe friction. During this phase of the model building process it is often necessary to supplement the data from prime sources with other information such as cover levels, invert levels, pipe sizes, pipe shapes, missing overflow pipes and carefully check the connectivity of the system.

Where simplification has been undertaken it is necessary to ensure that surcharge volumes are maintained in the model and these will be allocated to the remaining maintenance holes .A pipe roughness must then be allocated to each pipe length and this is initially done on the basis of the pipe material. The type of maintenance hole cover must also be allocated.

The next major step is to assign dry weather flows to each maintenance hole. This is done by using census data to allocate populations to each maintenance hole. Commercial and Industrial users are allocated separately where appropriate. Sydney Water has developed routines that allow water usage data to be used as a check against measured flow data. Sydney Water has also developed a range of flow profiles that can be used to model diurnal flow patterns.

Following establishment of the dry weather behaviour the wet weather behaviour must be determined. A hydrological model known as MOUSENAM is used to predict inflows to the sewer system in response to rainfall in the catchment. It is a lumped rainfall runoff model that classifies the wet weather flow hydrograph into a fast response component (FRC) and a slow response component (SRC). FRC is a direct consequence of rainfall and is not influenced by previous hydrologic conditions. SRC responds only slowly to rainfall and is highly dependent on previous hydrologic conditions. MOUSENAM is a combination of Surface Runoff Model that generates FRC and NAM model that generates SRC. Each model has a set of parameters that must be defined for each sub-catchment.

Having defined the physical characteristics of the pipe network and the wet and dry weather inflows it is then possible to undertake a hydraulic simulation of the network. Sydney Water has chosen to use the MOUSE model for this purpose. The MOUSE model can incorporate backwater effects, flow reversal, surcharging manholes, free surface and pressurised flow, tidal outfalls and storage basins. The model computes discharge and water level at alternating points throughout the network at each time step. To ensure the equation produces stable, physically realistic results it is necessary to run the model at time steps typically less than 60 seconds.

Output from the MOUSE model is in terms of flow and level at each point in the network. The model is calibrated by selecting a known period of time and adjusting the input variables described above until a match is made between measured flow and level and computed flow and level. The model is then verified by choosing another period of time and without modifying any of the calibration parameters observing the fit between measured and modelled flow and level.

2.3 Performance Indicators

The proposed performance indicators and acceptance criteria for calibration have been discussed in PRP101.1. Prior to testing for the performance indicators it will be necessary to test for gauge accuracy to ensure the gauge meets its acceptance criteria. Having ensured the gauge data complies with its acceptance criteria it is then

permissible to test for the performance indicators. There are three performance indicators and these are water level in the sewer, flow in the sewer at each gauge location and sewer overflow index.

2.4 Summary of acceptance criteria for calibration

There are three criteria to be applied to the comparison of measured water level and flow with modelled estimates in order that the model overall be accepted;

- No significant temporal bias
- No significant magnitude bias
- The minimum acceptable Pearson's Correlation Coefficient is 0.75

In addition the minimum acceptable overflow incidence index is 75%. The development of these criteria is detailed in PRP101.1.

3. TRIGGERS FOR RE-CALIBRATION

3.1 Introduction

Each of the models being developed for the trunk sewerage system will undergo a comprehensive process of model development, calibration and verification. These models remain in calibration until physical changes occur in the system. This assumption can be tested by annual comparisons of the model to data collected at licence gauge locations. The decision to re-calibrate a model should be based on the results of comparing measurements at the licence gauge with predictions from the model. These comparisons become the primary trigger for re-calibration.

There are also other reasons why the model may need to be updated and this may not require re-calibration of the model. The main reasons are listed below.

- System geometry and components changes
- New pipes or modifications to existing pipes
- Overflow weir level changes
- Pump station upgrades
- Changes to operating rules
- Wet weather flow behaviour
- Effect of leakage reduction works

3.2 Primary trigger

It is proposed that load be calculated annually using the trunk sewerage system models. This will require that the models need to be run using the last year's rainfall data to calculate flows and levels throughout the system. In each sewer system there will be at least one gauge measuring flow and level. It is appropriate at that time to compare the model prediction with the measured water level and flow at the licence gauge locations. The performance acceptance criteria discussed in section 2.4 can then be applied to see if the model has remained in calibration for the past year.

As described in PRP101.1 the acceptance criteria for a calibrated model are close to what is physically possible given errors in measurement and modelling. It is statistically likely that small excursions from the acceptance criteria will occur for a selected subset of the data. (such as using only one year of data rather than the whole record). Large excursions such as a change of 0.1 in the Pearsons Correlation Coefficient is unlikely to occur unless a significant physical change in the catchment has occurred.

It is proposed that this annual test of model accuracy be applied to each system as the primary trigger for assessing the need to recalibrate. This test would require that the immediate past year would be run through the model and the results compared to the original calibration acceptance criteria.

If the Pearsons Correlation Coefficient were less than 0.65 in the year this would trigger the need to begin the re-calibration process immediately. This process would be completed by the following year. If the Pearson's Correlation Coefficient is between 0.65 and 0.75 in each of two consecutive years then this would also be a trigger for re-calibration .If the Pearson's Correlation Coefficient is greater than 0.75 there is no need for re-calibration.

3.3 Other reasons to update the model

There are two main reasons for modifying the model. They are changes to system geometry and the effect of leakage reduction works. These will require a local modification to the model and not a system wide re-calibration. These changes are required to ensure that the basic assumptions of the model remain valid. These factors should be monitored on an annual basis.

3.3.1 System geometry and components

The MOUSE model is comprised of a network of pipes, maintenance holes, and pump stations, rising mains and overflow structures. Clearly if there are significant changes to this network they will need to be incorporated into an updated model .An obvious example is the construction of the Northside Storage Tunnel which comprises of a long tunnel, penstocks, inlet/overflow structures and pump stations. This major change in the trunk network would drive an update of the model.

As the MOUSE model only incorporates the major trunk mains it will not be necessary to modify the model if only changes to pipes outside the current model extent has occurred. Amplification of trunk mains within the model extent will need to be incorporated into the model as they occur but it will be sufficient to accumulate these and incorporate them in an annual update. Physical changes of this type will not necessitate a re-calibration of the model but rather a simple modification of pipe data in the MOUSE model.

Pump stations can have a significant influence on flow and level behaviour. Sydney Water has a program to reduce the risk of overflow at many of the pump stations and this will potentially effect system behaviour. Modifications to pump stations should be incorporated into the annual model update.

Changes to overflow weir levels can also have a significant effect on flow and level behaviour in the system. These will need to be incorporated into the annual update of the model.

3.3.2 Leakage reduction works

Wet weather flow behaviour will be influenced over time by leakage reduction works undertaken in the catchment. Typically a sub area of a catchment will have a program of works undertaken to reduce the amount of leakage which occurs in the sub area. As the trunk sewerage system models extent typically terminates at a sub area this improvement to behaviour will be reflected in changes to the inflow hydrograph and reticulation overflow behaviour. The trunk sewerage system models should be updated for this effect once the post-gauging program for the particular subarea is complete.

4. DATA REQUIREMENTS FOR RE-CALIBRATION

4.1 Model Build

As the models exist for each sewerage system the existing parameters become the basis for re-calibrating the model. The model build process covers the following steps

- model network definition
- data clean up
- processing and application of network asset data
- processing and application of catchment asset data
- modelling ancillary structures
- model simplification
- model export and stability check

A review of these steps is required to ensure that the current system reflects the existing model structure.

4.2 Rainfall

Rainfall data will be required covering a period of at least one month prior to the commencement of flow gauging for calibration purposes. Rainfall data has been shown to be critical in obtaining good correlation between measured and predicted flows. Where possible access should be made to all of the rainfall data Sydney Water collected in the catchment area of interest .The location of rainfall gauges needs to be plotted with reference to the location of sub-catchments and there topographic contours to 10m accuracy. From this plot it will be possible to assign rain gauges to each sub-catchment

A review of rainfall data is required to understand the quality of the data and to investigate the spatial variability of the recorded data. The data for each rain gauge should be compared to identify

- Rain gauges with missing or lost data
- Spurious or inconsistent data
- Spatial trends

Where data from a rain gauge is inconsistent or there is doubt over its validity, it should ideally be rejected. Where data from a rain gauge is considered suspect for only part of its record, the data should be rejected.

4.3 Flow Gauges

The extent of flow gauging required to be re-calibrated will depend on the size of the network and the number of licence monitoring gauges that failed the primary trigger. If a new set of gauging data is required the protocol for selecting the number of gauges shall be as described in PRP104.2.

The flow data to be used for calibration should be inspected to establish its suitability for its use in the calibration task .The flow and level data collected at each gauge are routinely audited to ensure they are unbiased and meet accuracy specifications. The results of these audits need to be reviewed prior to their use in calibration.

The CSIRO Division of Mathematical and Information Sciences has developed the gauge accuracy tests. They are conducted on velocity and level measurements. The tests are designed to check for gauge bias and variation .The gauge is required to be unbiased and variances must not exceed $10mm^2$ for level or $0.009m^2/s^2$ for velocity.

Other aspects of the flow data, which should be considered, are;

- The completeness of record
- Consistency of dry weather over the survey period
- Availability of both flow and depth data during storm events
- Synchronisation between rainfall and storm flows

Where data from a flow monitor does not meet the accuracy tests, it should be rejected.

4.4 Selection of a Dry Weather Period

During the review of flow data the modeller should identify the optimum week of data to calibrate the model for dry weather flow. The selected week will ideally have the following characteristics:

- All monitors have returned a full record of suitable data
- There has been no significant rainfall in the preceding week
- There has been no public holidays or other “extraordinary “events
- Not during school holidays

It is often difficult to achieve all of the above criteria and so a compromise will generally be necessary. The objective of the exercise is to establish the normal “representative” pattern of weekly diurnal flow at each monitoring site.

4.5 Selection of a Wet Weather Period

The selection of appropriate wet weather events is critical to successful model calibration. Criteria for events selected for calibration include:

- The set should include a range of rainfall events from relatively short intense storms to longer, soaking rains to best enable both the fast and slow response components to be identified.
- Minimal spatial variation in recorded rainfall across the rain gauge network.
- Some of the events should result in system surcharge to assess the suitability of un-modelled storage estimates and the interface between the hydraulic and hydrologic models.

The minimum number of events that will be needed are two to define fast and slow response parameters and a third to define system surcharge behaviour. It will normally require at least three months of monitoring to find three storms that meet these criteria.

5. RE-CALIBRATION METHODOLOGY

5.1 Introduction

Once the primary trigger has been exceeded it will be necessary to modify the model. There are two basic areas that may require modification and these are in the model building process or in the model calibration process. The model building process refers to the physical features of the network such as catchment area, model network definition, ancillary structures, asset data, catchment hydrologic data and model simplification process.

The re-calibration process is that associated with adjusting the hydrologic parameters within the model so that the dry weather and wet weather behaviour represents measured flow behaviour. This chapter discusses the re-calibration methodology, the procedures for this method are included in the quality management system for models.

5.2 Model Building

Trunk sewerage system models have been built up using standard procedures. Changes to the physical system are incorporated in the model building phase. These have been discussed previously and relate to major physical changes to the system such as

- New pipes
- Overflow weir level change
- Pump station upgrades
- Changes to operating rules

Changes to these parameters should be recorded and the model updated annually. Changes in the model build process do not require re-calibration of hydrological parameters as discussed below.

5.3 Model Re-calibration

5.3.1 Introduction

Model re-calibration will require examination and modification of both dry and wet weather parameters. This requires the collection of flow and rainfall data as described in section 4. Calibration of both dry and wet weather flows requires the catchment to be divided into monitored catchments. A monitored catchment is described as the sub-catchments upstream of each individual flow monitor. The characteristics of each monitor catchment are adapted to produce the best fit between observed and predicted data. At all times it is important to ensure that the parameters remain within sensible limits and do not vary dramatically within a small area without justification.

5.3.2 Dry Weather

The sources of inflow to a sewerage network during dry weather are as follows:

- Residential Population derived flows
- Commercial /Industrial flows
- Ground Water Infiltration (GWI)

During the model building phase a table for each sub-catchment is developed and this contains the following details:

- Residential population
- Residential water consumption
- Commercial /Industrial water consumption
- The down stream flow monitor

A site specific per capita flow rate for residential flows is then calculated by taking the flow from the selected period and subtracting the commercial /industrial sewage flows (assuming 90% of water consumption) from the average daily flows for each monitor. This will provide an estimate of the residential flow for the catchment. These values will be used in the sub-catchments applicable.

The MOUSE model allows a number of dimensionless weekly profiles to be applied to the residential and commercial/industrial flows to simulate the diurnal patterns of dry weather inflows .The residential patterns will be affected primarily by socio-economic factors while the commercial /industrial flows will be a function of the specific activity undertaken.

Once all estimated inflows have been input into the model an eight day dry weather simulation starting 24 hours before the selected dry weather period should be commenced. The initial 24 hours will ensure that the flows are fully initialised for the start of the calibration period.

The results of this simulation should be compared visually in the first instance against measured data. Adjustments to diurnal flow profiles, per capita flow rates for

residential flows are made until a good fit between observed and predicted is achieved.

5.3.3 Wet Weather

The wet weather behaviour of the model should be established by reference to at least three storms. The first two storms should be small enough to cause a response within the sewer but not large enough to cause an overflow. The third storm should be representative of a storm which causes wide spread overflow. When the model can reproduce the behaviour of the system for a small, medium and large storm it is considered to be calibrated. The model must then be verified on an extended time series.

5.3.4 Model Verification

Model verification is the process of subjecting the model to testing over a minimum of a 3 month time series to see if it can achieve the performance acceptance criteria described in PRP101.1 and reproduced in Chapter 2. It should also have a range of events from small events that do not surcharge the system to large events that result in significant overflows. To achieve this a longer verification period than 3 months may be required.

6. CONVENING A CRITERIA REVIEW COMMITTEE

PRP101.4 requires an independent Criteria Review Committee (CRC) to confirm that the trunk sewerage system models meet the approved performance acceptance criteria following the completion of calibration, which is required by 31 October 2001. This PRP also requires that the re-calibration protocol must also be reviewed by the CRC. It is proposed that the CRC meet by 31 April 2001. At this time the majority of models will be calibrated and the tests will be available for the CRC to determine whether the stated acceptance criteria have been met. By holding the CRC at this time it will be possible to accommodate the CRC recommendations prior to the final completion date of 31 October 2001.

Attachment 6 Sydney Water QMS Certification

bsi.

Certificate of Registration

QUALITY MANAGEMENT SYSTEM - ISO 9001:2015

This is to certify that:

Sydney Water Corporation
1 Smith Street
Parramatta NSW 2150

Holds Certificate Number: **FS 683290**

and operates a Quality Management System which complies with the requirements of ISO 9001:2015 for the following scope:

Please see scope page.

For and on behalf of BSI:

Charlene Loo, Managing Director, BSI Group Australia & New Zealand

Original Registration Date: 2018-05-10
Latest Revision Date: 2024-05-15

Effective Date: 2024-05-15
Expiry Date: 2027-05-09

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Certificate No: **FS 683290**

Registered Scope:

To plan, deliver, operate, manage, maintain, and improve the systems, services and products for water, wastewater, recycled water, stormwater, and other recovered resources for Sydney Water Customers throughout its area of operations.

This is a Multi-site certification and details of the site addresses and respective activities are retained with BSI System Certification. Due to privacy and confidentiality regulations, site information including name, relevant normative document, scope and geographical location (e.g. city and country) for each certified client (or the geographic location of the headquarters and any sites within the scope of a multi-site certification) shall be requested directly from the certified client.

Previous Certificate expires on 2024-05-09
Recertification audit ended 2024-03-20

Original Registration Date: 2018-05-10
Latest Revision Date: 2024-05-15

Effective Date: 2024-05-15
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Attachment 7 Criteria Review Committee (CRC) on Trunk Modelling

Prepared for

Australian Water Technologies

CRC on Trunk Modelling

Professional Services Contract No ENC 339

Draft Report for SWC Review

Reference: 110328

May 2001

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Executive Summary

Objectives of CRC

PRP 101.4 in the Environmental Protection Licences requires that Sydney Water should convene an independent Critical Review Committee (CRC) to confirm that the trunk sewerage system models meet the technical specification as proposed in PRP 101.1 and 101.2. The specific objectives of the CRC, as provided by Sydney Water, are shown in **Table 1.1**.

CRC Members

The members of the CRC are as follows:

- Dr Jeppe Nielsen. Manager Catchment Planning, CH2M HILL Australia (Chairperson).
- Mr Sam Austin. General Manager, Asset Services, Yarra Valley Water.
- Mr Daniel Large. Manager Environmental Information and Statistics, NSW EPA.
- Mr Glenn McDiarmid. Senior Consultant, Gutteridge Haskins & Davey.
- Mr Neil Moody. Principal, Moods Consulting.

Meeting Procedure

The CRC met on 16 and 17 May, 2001, in the Nepean Room, Sydney Water Business Office, Interchange Building, 432 Victoria Avenue, Chatswood. The agenda and presenters are shown in **Table 1.2**.

Presentation of CRC Findings

This report describes the findings of the CRC under the following main headings:

- Overall findings; and
- Specific findings with respect to each of the objectives listed in **Section 1.2**.

Overall Findings of the CRC

The CRC was appreciative of Sydney Water's candour. It is acknowledged that building, calibrating and applying sewer models for simulating sewer overflows for licensing purposes is a learning exercise for all concerned. However, it is evident that Sydney Water and the EPA have a common will to ensure that the modelling process is successful.

The CRC also recognises the large extent of work that has been undertaken by Sydney Water since the last CRC.

However, the CRC has identified a number of issues that may impact on model recalibration and benchmarking, including the ability to meet performance acceptance criteria, high flow

gauge calibration, the appropriate level of model detail and the adequacy of the data for benchmark model recalibration.

Specific Findings of the CRC

The following specific findings are presented under each of the CRC objectives (refer Section 1.2).

Review Actions Completed by Sydney Water Regarding Recommendations of the previous CRC

Significant progress has been made for all the recommendations that are relevant to this CRC (refer **Table 3.1)**.

Quality Plans

The content and implementation of the Quality Plans were generally considered to be satisfactory. The CRC supports the continued use of internal auditing and recommends that the auditors take account of the recommendations made in this report.

*However, the CRC recommends the inclusion of a number of additional procedures in SSEPQP003_001, SSEPQP003_002 and SSEPQP003_003. The recommended additional procedures are summarised in the "Conclusions and Recommendations" (**Section 4.2.2**).*

Appropriateness of the Proposed Performance Acceptance Criteria Used for Re-Calibration of Trunk Models

Performance Indicators

The CRC considers that pipe level and flow are appropriate performance indicators for the trunk sewer models because corresponding measured and model results can be obtained and compared. Although in principal the Overflow Incidence Index is a sound performance indicator because it provides a measure of a model's ability to simulate the occurrence of overflows, the CRC considers there are problems with its use as a calibration parameter in view of data limitations and the calculation method. Furthermore, it should only be used if the models have been demonstrated to be unbiased in terms of magnitude and time.

Sydney Water should continue to use the following two performance indicators for calibrating the trunk sewer models: level above pipe invert and sewer flow. The Overflow Incidence Index should not be used in its present form as a primary recalibration parameter. Its method of calculation should be revised. It should then be used to confirm a models capability for predicting the occurrence and duration of overflows.

Performance Acceptance Criteria

Sydney Water has nominated four performance acceptance criteria - magnitude and temporal bias tests, the Pearson Correlation Coefficient (reported as r^2) and the Overflow Incidence Index. It is not clear why Sydney Water has concluded that a model needs to pass all of the acceptance criteria in order to be recalibrated.

The two bias tests are non-parametric tests whereas the r^2 test assumes that the data are normally distributed. The CRC has identified issues with the use of the Overflow Incidence Index. It can be concluded that a model reproduces the occurrence of overflows in terms of

magnitude and time if it if passes the two bias tests (assuming that the flow gauges have been calibrated for all flows).

The two bias tests should be the primary performance acceptance criteria.

The r^2 test should only be used if it can be demonstrated that the data are normally or approximately normally distributed.

The calibration protocol should be revised to separately use dry and wet weather data for statistical verification of recalibration results instead of the use of data for all flow conditions, as is current practice (to avoid the possibility of wet weather data being "swamped" by more numerous dry weather data).

Non-statistical "common-sense" criteria should be used in addition to statistical criteria for calibrating the models. The relevant non-statistical performance acceptance criteria are that the model results are unbiased if differences between measured and modelled levels and flows are less than 10 mm or 5% of average dry weather flow (ADWF), respectively.

Measured, operating and model data should be plotted or otherwise reviewed before statistical analyses are undertaken. In other words, the acceptance criteria should be viewed as a supplement to good modelling practice, not a substitute.

The sampling frequency of SWAGMAN should be reviewed and adjusted as necessary for each trunk sewer model so that the full range of data are used.

Calibration Process for a Selection of Completed 1994 Trunk System Benchmark Models and Results for Available Completed Models

Review Appropriateness of Steps Undertaken to Transfer Models to OACIS Platform, Undertake Statistical Tests and Verification of the 1994 Benchmark Models.

It is understood that all of the 27 STS trunk sewer benchmark models have been transferred to the OACIS platform. The recalibration process provides confidence that the transfer of the trunk sewer model to the OACIS platform has been undertaken satisfactorily.

The CRC is satisfied that the statistical requirements specified in SSEPQP003_002 are being followed by the trunk sewer modellers. However, the CRC has concerns about the way in which the acceptance criteria are calculated and used, as summarised above.

Eight STS benchmark models are being recalibrated for dry and wet weather flows and statistically verified. Recalibration/verification of these models is not completed. The CRC considers that the models will have been recalibrated and verified as far as possible using the available data when the issues identified in the Sydney Water presentations and in this report have been addressed.

Several of the model presentations indicated that data used for recalibration and statistical verification are considered to be of inadequate quality and/or quantity.

The CRC recommends that where inadequate data prevent successful benchmark model recalibration, Sydney Water should identify a more recent and improved period of calibration data and update the benchmark trunk sewer models with the newer and improved data.

However, Sydney Water would need to demonstrate that the sewerage system has not deteriorated during the time from the current benchmark model (1991) to the recalibrated model using the newer data in order for the EPA to accept the calibrated model using the newer data as the new benchmark model.

Do the Re-Calibrated 1994 Benchmark Models Now Meet the Specified Acceptance Criteria?

Twenty six of the 64 flow gauges in these eight STS models pass all of the performance acceptance tests. However, none of the recalibrated 1994 benchmark models meet all of the specified acceptance criteria.

The reasons for incomplete model calibration include inadequate rainfall, sewage pump station (SPS) operations and sewer gauge data across catchments for the 10 year (1985 to 1994) time series, and insufficient model detail.

CRC recommendations concerning these issues are summarised in the "Conclusions and Recommendations" (**Section 4.2.4**). Major issues concern the lack of high flow calibration of gauges and the need to augment the STS models with SCAMP data.

There are also concerns that physical changes in catchments over time, eg population increases, SPS upgrades and changes to sewers, are not being adequately included in the models. The CRC is also concerned about the extensive use of virtual nodes in models and some model build parameters, eg the spacing of grid points used.

The CRC considers that modellers should routinely communicate with sewerage system operators in order to obtain improved understanding of the sewer systems being modelled.

If not, have all steps been taken to calibrate the model given input data availability and accuracy?

The CRC considers that when the issues identified in the presentations and in this report have been addressed the models will have been recalibrated and verified as far as possible using the available data.

Are the actions identified by Sydney Water to improve these models appropriate?

Several actions have been identified by Sydney Water to improve model calibration. Most of these actions are under way and should result in improved model calibration. The CRC also considers that recommendations presented in this report will need to be implemented for satisfactory model calibration and benchmarking.

Comments are made in this report concerning the need for modellers to review raw data, ie levels, flows and other operating data, prior to statistical analyses and to communicate with sewerage system operators to obtain better understanding of STS operations.

It is also recommended that modellers review SCAMP data, including maintenance records, customer complaints and choke data, to obtain additional verification data.

Furthermore, it is strongly recommended that modellers regularly discuss problems, issues and successes with each other to obtain mutual support and maximise operational knowledge of the models.

The CRC also strongly recommends that Sydney Water should develop a protocol for system models that appear not able to be recalibrated to the adopted performance acceptance criteria, as required in PRP 101.2.

The Proposed Model Re-Calibration Protocol Specified in Report PRP 101.2

The protocol appears logical and practical, although it is a generic protocol and little detail is presented. However as noted above, the issue of models that are unable to meet the adopted performance acceptance criteria has not been adequately addressed.

The CRC recommends that the adequacy of three months/three storm events for recalibration purposes needs to be demonstrated. The adequacy of the primary trigger (r^2) *should also be demonstrated and revised as necessary.*

Associated Model Re-Calibration Processes that are being Implemented by Sydney Water

The necessary processes for maintaining and updating model calibration were not covered in detail in the Sydney Water presentations to the CRC. The CRC suggests that this topic should be addressed at a later date when the issues and recommendations by this CRC, as presented in this report, have been addressed.

In principal the CRC agrees that the trunk sewer models should be maintained as calibrated models for sewer overflow licensing purposes. The CRC makes the following preliminary comments at this stage:

- Significant system changes should be identified for use as triggers to determine which models should be updated and recalibrated. Suitable triggers could include ADWF, customer complaints and incidences of overflows. It is suggested that models would not be considered for recalibration unless trigger values had changed significantly since the model was last revised.

- Suitably skilled resources will need to be made available to meet the modelling requirements as specified in the STS licences. It is noted that Sydney Water may find it difficult to meet licence delivery dates for all STSs with existing resources.

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Abbreviations	
ADWF	Average Dry Weather Flow
CRC	Critical Review Committee
EPA	NSW Environmental Protection Authority
NSW	New South Wales
POEO	Protection of the Environment Operations
PRP	Pollution Reduction Program
r^2	Square of the Pearson Correlation Coefficient value
SCAMP	Sydney Catchment Area Management Plan
SOLP	Sewerage Overflow Licensing Programme
SPS	Sewage Pump Station
STP	Sewage Treatment Plant
STS	Sewage Treatment System

1 Introduction

1.1 Background

Following an intensive community and stakeholder consultation process involving submission of Environmental Impact Statements, Sydney Water has been issued Environmental Protection Licences from the NSW Environmental Protection Authority (EPA) under the Protection of the Environment Operations (POEO) Act for each of its 27 sewage treatment systems (STSs). The licences are issued for the scheduled activity of operating a sewerage treatment system. They are combined licences in that they include both the sewage treatment plant (STP) and sewage transport /reticulation system. Discharges from all components of the sewage transport /reticulation system owned and operated by Sydney Water are included in the licence and include sewage pump stations (SPSs), sewer lines, vents, siphons, overflow points and access chambers.

The STS licences include several requirements, including:

- Administrative conditions;
- Defining discharge, monitoring and reporting points in the STSs;
- Setting limit conditions for loads, volumes, masses, concentrations and frequencies of sewage overflow discharges;
- Operating conditions;
- Monitoring and recording conditions;
- Reporting conditions;
- Pollution reduction programs; and
- General conditions.

Sydney Water has developed computer system models for its sewerage network to predict the performance of the STSs under wet weather conditions. The models are used to predict frequency, volume and duration of overflows for specified rainfall events.

There are a number of Pollution Reduction Programs (PRPs) in the environmental protection licences that require either the provision of technical reports to the EPA or specific works and activities to be undertaken to deliver improvements to STS performance. The PRPs that are relevant to this CRC address the performance of the system models developed by Sydney Water and can be summarised as follows:

- PRP 101.1: Development of Approved Performance Indicators and Performance Acceptance Criteria;

- PRP 101.2: Generic Model Recalibration Protocols; and
- PRP 101.3: Recalibration of Models.

1.2 Objectives of CRC

PRP 101.4 in the Environmental Protection Licences requires that Sydney Water should convene an independent CRC to confirm that the trunk sewerage system models meet the technical specification as proposed in PRP 101.1 and 101.2. The specific objectives of the CRC, as provided by Sydney Water, are shown in **Table 1.1**.

Table 1.1 Objectives of the CRC

1	Review the appropriateness of the proposed performance acceptance criteria used for re-calibration of the trunk models and specified in report PRP 101.1. against the use of the models for licence reporting and compliance. • The criteria have been reviewed in a previous CRC, however, there have been some minor changes to selection of indicators and targets that require review.
2	Review the calibration process for a selection of completed 1994 trunk system benchmark models and results for available completed models at the time of the CRC. • Review appropriateness of steps undertaken to transfer models to OACIS platform, undertake statistical tests and verification of the 1994 benchmark models. • Do the re-calibrated 1994 benchmark models now meet the specified acceptance criteria? • If not, have all steps been taken to calibrate the model given input data availability and accuracy? • Are the actions identified by Sydney Water to improve these models appropriate ?
3	Review the proposed model re-calibration protocol specified in report PRP 101.2 • Is the re-calibration protocol appropriate to meet ongoing licence compliance and reporting requirements; • Does the re-calibration protocol ensure that the models will continue to meet the proposed performance acceptance criteria.
4	Review of associated model re-calibration processes that are being implemented by Sydney Water to ensure that the models will continue to meet the performance acceptance criteria. Include: • Review of the appropriateness of the trunk model quality system, in particular review of the annual return reporting procedure; • Review of the appropriateness of Sydney Water's proposed scheduling of CRCs against current STS licence requirements.

The following two additional objectives were also identified:

- Review the CRC recommendations of the previous CRC of May 2000 and actions completed by Sydney Water; and,
- Review the Quality Plans developed by Sydney Water since the previous CRC.

1.3 CRC Members

The members of the CRC are as follows:

- Dr Jeppe Nielsen. Manager Catchment Planning, CH2M HILL Australia (Chairperson).
- Mr Sam Austin. General Manager, Asset Services, Yarra Valley Water.
- Mr Daniel Large. Manager Environmental Information and Statistics, NSW EPA.
- Mr Glenn McDiarmid. Senior Consultant, Gutteridge Haskins & Davey.
- Mr Neil Moody. Principal, Moods Consulting.

1.4 Meeting Procedure

The CRC met on 16 and 17 May, 2001, in the Nepean Room, Sydney Water Business Office, Interchange Building, 432 Victoria Avenue, Chatswood. The agenda and presenters are shown in **Table 1.2**.

All of the Sydney Water presentations took place, although the times of some presentations differed from those in **Table 1.1**.

Table 1.2 Agenda and Presenters for CRC		
Time	**Topic**	**Presenter**
Wednesday, 16 May 2001		
8:30	Introductions / Agenda / CRC Conduct	R Keessen/J Nielsen
8:45	CRC Objectives	P Fisher
9:00	Background – STS licences, key licence requirements related to models	W Eyles
9:30	SSEP QMS Trunk Models Overview	S Frtunik
9:45	Question and Answer Session	
10:00	Morning Tea	
10:15	Review of recommendations from previous CRC related to trunk models	A Kasmarik
10:30	PRP 101.1 – Proposed Acceptance Criteria	A Kasmarik
11:00	Trunk Sewerage System Model Methodology and Re-calibration Process	M Mohanathasan
11:40	Question and Answer Session	
12:00	Lunch	
12:30	West Hornsby System Calibration and Results	W Cox
13:30	Question and Answer Session	
14:00	Afternoon tea	
14:20	CRC panel closed session	
17:00	Close	
18:00	Dinner	
Thursday, 17 May 2001		
8:30	West Camden System Calibration and Results	N Brown
9:30	Summary / Progress / Key Issues for other systems	K Goodhew T Loxton, B Griffiths, M Mohanathasan
10:10	Question and Answer Session	
10:30	Morning Tea	
10:45	PRP 101.2 re-calibration protocol	M Mohanathasan
11:00	STS Licence - Annual return requirements	S O'Donoghue

Table 1.2 Agenda and Presenters for CRC		
Time	**Topic**	**Presenter**
11:15	Summary issues for Trunk Model / Closing comments	R Keessen
11:30	Final Question and Answer Session	
12:00	CRC Panel closed session	
13:00	Lunch	
15:00	CRC Panel closed session	
16:30	CRC Panel Discussion / Review of major findings	
	Close	

1.5 Presentation of CRC Findings

This report describes the findings of the CRC under the following headings:

- Overall findings; and
- Specific findings with respect to the objectives listed in **Section 1.2**.

2 Overall Findings of the CRC

The CRC makes the following general comments:

- The CRC was appreciative of Sydney Water's candour in discussing work carried out to date and problems that have been overcome and still remain to be solved.

- It is acknowledged that building, calibrating and applying sewer models for simulating sewer overflows for licensing purposes is a learning exercise for all concerned, particularly Sydney Water and the EPA.

- It is evident that Sydney Water and the EPA have a common will to ensure that the modelling process is successful.

- The previous CRC recommended that "Sydney Water and the EPA continue negotiations to resolve current differences in investigating and licensing sewerage overflows". Sydney Water personnel indicated that positive negotiations between the two organisations had largely resolved earlier differences.

The CRC also recognises the large extent of work that has been undertaken by Sydney Water since the last CRC. Considerable progress has been made in the following specific areas:

- Improved project planning and management;

- Implementation of quality systems;

- Application of model performance criteria;

- Draft protocols for PRPs;

- Improvements in in-sewer flow gauging during higher flow conditions;

- Internal auditing;

- Improved understanding of the sewerage system; and

- Use of OACIS has improved transparency and coordination.

However, the CRC identified the following issues, which are discussed more fully in this report:

- Ability to meet performance acceptance criteria;

- The lack of protocols for statistically non-complying STS models;

- Impacts of future improvements to the high flow calibration of gauges and models need to be investigated;

- Sufficient detail in the trunk models is required to minimise the proportion of system overflows and hydraulic details that are represented by virtual nodes;
- Systematic augmentation of the trunk models with data that has been collated and verified as part of the Sydney Catchment Area Management Plans (SCAMPs);
- Better spatial resolution of rainfall data;
- Ongoing need for improved operational knowledge (eg pump settings etc);
- The extensive amount of work to meet EPA licence deadlines; and
- Availability of suitably skilled resources for model recalibration, benchmarking and SCAMP programs.

3 Specific Findings of the CRC

3.1 Review Actions Completed by Sydney Water Regarding Recommendations of the previous CRC

The recommendations made by the previous CRC are presented in **Table 3.1**.

It should be noted that several recommendations of the previous CRC (held in May 2000) were not included in the objectives for the current CRC, as noted in **Table 3.1**. The focus of the present CRC was on the procedures for model calibration and verification that Sydney Water has developed and implemented since the previous CRC.

Comments of the present CRC are included for previous recommendations that are relevant to the objectives of the present CRC. Significant progress has been made for all the recommendations that are relevant to this CRC.

Table 3.1 Findings of Previous CRC (May 2000) and Actions Completed

CRC May 2000 recommendations	Current status	Comments by this CRC
Several recommendations from the previous CRC have not been completed or commenced by Sydney Water. These relate mainly to the preparation of Management Plans and various protocols associated with SCAMP development.	Management plans have been prepared for all SCAMP work. A management plan has also been prepared for the recalibration of the Strategic models.	The SCAMP management plan is not a topic for this CRC.
An overall Management Plan for the entire 20 year $2 billion Overflow Abatement Program is completed as soon as possible. It should be used as the basis for more detailed shorter term Management Plans. The Management Plan should be updated as overflow planning priorities and investigation methods are revised or changed. Additional SCAMPs should not be commenced before the Management Plan is available.	A Management Plan has been prepared.	The Management Plan was discussed with the CRC. The detail of the Plan is not a topic for this CRC.
The investigation and QA/AC protocols that are to be followed for all phases of SCAMP investigations are completed as soon as possible.	Quality Plans have been completed.	The following Quality Plans were presented to the CRC: • SSEPQP003_001 (Trunk Model Build) • SSEPQP003_002 (Model Calibration & Verification) • SSEPQP003_003 (Model Modification & Recalibration) Comments regarding these plans are presented in **Section 3.2**.
Sydney Water has commenced too many SCAMPs without implementing documented management procedures. The CRC considers that only sufficient SCAMPs should be completed to refine skills development of staff and to validate the methodologies to completion so that completed investigation protocols and QA/QC procedures can be prepared.	Document management procedures now exist. These include QA/QC procedures for modelling and planning. They apply to the strategic models as well as the SCAMP models. 25 SCAMPs are currently in progress. The Chatswood and Concord West SCAMPs have reached the options stage.	Trunk modelling management plans were presented to the CRC. They are considered to be appropriate.

Table 3.1 Findings of Previous CRC (May 2000) and Actions Completed

CRC May 2000 recommendations	Current status	Comments by this CRC
All SCAMP models, whether undertaken by Sydney Water or by others, should be independently audited.		Not a topic for this CRC.
The CRC is concerned by the lack of integration and communication between the OACIS modelling, Environmental Assessment and Community Communication programs. Timing, level of detail and dialogue between the three programs needs to be addressed. The existing OACIS Scope of Work should be modified to incorporate formal feedback from the Environmental Assessment and Community communication programs and that appropriately integrated Scopes of Work be prepared for the Environmental Assessment and Community Communication programs.	Procedures for integrating the three environmental planning components have been built into SCAMP planning procedures. The environmental planning module of OACIS has been incorporated into the software and the work instructions.	Not a topic for this CRC.
Is the SCAMP prioritisation process appropriate? A more quantitative ranking methodology should be developed. Sydney Water should consider using risk assessment methodology for this purpose.	SCAMP planning has been fast tracked to be completed by July 2003. Prioritisation is based on EPA requirements, growth and known operational problems. The speed of the planning process will ensure all problems are addressed in a short time.	Not a topic for this CRC.
Sydney Water should establish an overarching consultative group that comprises peak environmental bodies to provide input and to validate the SCAMP prioritisation process	This recommendation has not currently been adopted. All consultation is being carried out with local interest groups using the local Council as a focus point.	Not a topic for this CRC.
Sydney Water should clarify the extent of community communication that is proposed.	The community consultation plan is still being developed although the principles have been trialed in the Chatswood SCAMP.	Not a topic for this CRC.
The Community Communication Plan should be developed and more closely integrated with the other SCAMP investigation and planning methodologies.	This has occurred in the Chatswood SCAMPs and is currently occurring in the Blue Mountains SCAMPs.	Not a topic for this CRC.

Table 3.1 Findings of Previous CRC (May 2000) and Actions Completed

CRC May 2000 recommendations	Current status	Comments by this CRC
Sydney Water should undertake a database search to determine whether other relevant sources of data should be used.	The consultation phase and information gathering phase with local councils checks for all relevant data available in the local communities. The consultation with the operators of the sewerage systems similarly searches for any local additional system information. To date the information gathered has been adequate for decision making associated with SCAMP planning.	Not a topic for this CRC.
Flow gauges should be calibrated at medium and high in-pipe flows which are likely to cause overflows as well as at low flows.	This recommendation has been adopted in the new gauging contracts that commenced in November 2000.	Calibration has been undertaken for flows up to 70% full pipe flow. The CRC remains concerned that gauges have not been calibrated for full pipe flows.
Sydney Water develops a protocol for applying the statistical and non-statistical tests in a consistent manner. Furthermore, the protocol should include requirements for checking and decision-making points which are to be signed off by the Manager or other qualified personnel.	Protocols were developed as part of PRPs 101.4.1 and 101.4.2.	Quality Plan SSEPQP003_002 (Model Calibration & Verification) was reviewed. Comments are provided below.
Sydney Water should address staffing issues relating to the possible need for more experienced SCAMP personnel and for the preparation of Management Plans and protocols.		Not a topic for this CRC.
Sydney Water and the EPA should continue negotiations to resolve current differences in investigating and licensing sewerage overflows.	STS Licences issued	Sydney Water is implementing licence PRPs. The CRC notes the higher level of cooperation between Sydney Water and the EPA.
A documented strategy be developed and implemented by Sydney Water so that appropriate accountabilities are defined for ownership and maintenance of the SCAMP tools and data for the life of the Overflow Abatement Program.	To be addressed.	Not a topic for this CRC

3.2 Quality Plans

The following Quality Plans were reviewed by the CRC:

- SSEPQMS001. Quality Management System Manual;
- SSEPQMS003. Trunk Sewerage System Modelling Operations Manual;
- SSEPQP003_001. Trunk Sewerage System Model Build Procedure;
- SSEPQP003_002. Trunk Sewerage System Model Calibration & Verification Procedure;
- SSEPQP003_003. Model Modification and Recalibration Procedure; and
- SSEPQP003_004. Model Annual Reporting Procedure.

These Quality Plans were generally considered to be satisfactory. However, the CRC has the following comments regarding the SSEPQP Quality Plans.

Review of SSEPQP003_001 (Model Build Procedure)

Defining Model Extent

A procedure should be included to incorporate sufficient hydraulic detail and constructed overflows so that the use of virtual reticulation nodes is minimised.

Pipe Conveyance (Model Link) Elements

The procedure should specify how pipe lengths have been aggregated in the simplified models.

Access Chambers

The only access chambers that discharge and are not formal overflow structures included in the trunk models are those determined by consultation with the regional operations personnel. It is possible that other chambers overflow and should be included. A suggested means of determining these chambers would be by simulating the most significant rain event through a fully detailed model and finding all points of discharge or where the hydraulic grade line rises above the surface level in a chamber. It could be argued that these points represent minor overflow locations, however, they are overflow points that may not otherwise be captured. Furthermore, the lids could be so tight at some or all of the access chambers that discharges do not occur. This can be determined by inspection, bearing in mind that if the chamber is accessed for maintenance the lid is no longer tight and discharge may occur after such access.

Reducing Model Size Using Equivalent Circular Sections

Where simplification of non-standard pipe shapes is undertaken by representing them as circular cross sections, the procedure should require verification that this simplification is appropriate for the full range of flows.

Reticulation Overflows Representation

The CRC has concerns about the use of virtual nodes and reticulation overflows. As demonstrated by the recalibrated model presentations, the major changes in overflow frequency occurred at these locations. It is considered that the use of virtual nodes should be minimised by representing currently unmodelled parts of the system as subcatchment models or the geometry of each model should be extended as appropriate.

Anecdotal Information

No procedure has been included for the collection of anecdotal information about the operation of the system. Prior to building the model all relevant personnel should be interviewed to determine their knowledge of the configuration of the system and the performance of the system. Furthermore, all reported system problems such as customer complaints, CCTV inspections and maintenance records should be obtained. These items are key elements of the SCAMP procedure. It is considered that the MOUSE modelling and SCAMP program need to be fully integrated.

This information may lead to additional components being included and/or less simplification of the network.

Unavailable Data

No procedures are included for dealing with unavailable data, eg missing pump station configuration data.

Logic Checks

No procedures are defined for undertaking model logic checks, eg are all pipes going downhill, are pipe sizes decreasing downhill, are pipe slopes excessive, is the downstream pipe lower than the upstream pipe at all chambers.

Check Off/Audit Procedure

There are no apparent check-off or audit procedures. Various details are required to be included in the project file to demonstrate they have been done or considered. However there is no check off procedure or form to verify that all relevant factors have been checked.

The CRC recommends the inclusion of the following procedures in SSEPQP003_001:

- *Inclusion of sufficient detail to ensure that the system is adequately represented and to minimise the use of virtual nodes and overflows;*
- *Specification of pipe lengths in simplified models;*
- *Inclusion of all relevant access chambers;*
- *Verification of simplification procedure of non-standard pipe shapes;*
- *Verification that all overflow points have been included in the trunk model;*

- *All anecdotal information has been obtained;*
- *For dealing with missing data;*
- *Logic checks; and,*
- *Check or audit procedures that all relevant factors have been considered.*

Review of SSEPQP003_002 (Model Calibration and Verification)

Hydraulic Parameters (Manning n) Calibration

The procedure allows for the Manning n value to be modified in the downstream links such that a good match of depth is obtained. The procedure does not specifically state that all links from one gauge point to the next should have the same Manning n value, unless there is evidence that this should not be the case. Furthermore, it does not specify the procedure to deal with the situation of two gauged links converging prior to a third gauge point, ie how to handle the common section if the Manning n value is apparently different for the two independent links.

It is noted that the flow pattern calibrations are undertaken simultaneously with the calibration of the hydraulic characteristics of the pipes, as represented by the Manning n values. These are different processes and should be calibrated independently.

Wet Weather Flow Calibration

The procedure indicates that the methodology described in Robert Carr's MOUSE RDII calibration guidelines should be used. This reference was not provided and cannot be commented on. The CRC considers that a generic wet weather flow calibration procedure should be included in the Quality Plan.

Furthermore, the use of virtual reticulation nodes is included. It is considered that the model build procedure should include sufficient detail to minimise the use of virtual nodes.

Verification of Model Suitability

The verification process comprises a statistical analysis of the gauged versus modelled level and flow results for the adopted calibration data. It is considered that this process should be extended. The hydrological process modelled includes three separate water storages – upper level (surface storage), lower level (root zone storage) and groundwater (water table level) – all of which impact on the amount of inflow/infiltration to the model. These storages should be in long term equilibrium.

All storages will exhibit increases and decreases over shorter time periods but not over longer time periods. Trends may be evident over a two to three year period due to el-nino/la-nina, but over the longer ten year period there should be no trends. In general the upper storage should show variations over its full capacity over short time periods (days) and the lower storage should have a "base level"

around which it will vary over a period of days to weeks. The groundwater level should also vary around an equilibrium level with variations upwards and sometimes downwards which can be over many months and sometimes years.

Attachment A: Audit Validation Check Points

This is considered to be a good audit procedure. However, it should include checks of all adopted hydrological process parameters and statistical bias tests of storages, as discussed above. It should also include a check that consultation with operators and field inspections has been undertaken.

The CRC recommends the inclusion of the following procedures in SSEPQP003_002:

- *To ensure that the same Manning n value is used between adjacent gauge points;*
- *To deal with different Manning n values for two independent gauged links with a common section;*
- *Separate calibration of flow and Manning n value;*
- *Bias tests should be applied to the three water storages (surface zone, root zone and ground water) using the ten year rainfall time series. This analysis should be included as part of PRP 101.1 System Model Performance Indicators.*
- *An explicit procedure for wet weather flow calibration;*
- *The audit validation should include checks of all adopted hydrological process parameters, statistical bias tests of storages and a check that consultation with operators and field inspections has been undertaken.*

Review of SSEPQP003_003 (Model Modification and Recalibration)

The details contained in this procedure are generic only.

The CRC recommends that the procedures in this Quality Plan should either be detailed as in the other Quality Plans or should refer to the other Quality Plans.

3.2.1 Implementation of Quality Plans

Sydney Water described the following procedures for implementing the quality plans:

- All modelling staff, including consultants, are trained to use the quality plans;
- Internal technical audits are undertaken at ten week intervals to ensure that modelling staff are complying with the quality plans;
- Relevant staff are trained whenever quality procedures or the models are changed.

The CRC considers that implementation of the quality plans has been satisfactory.

3.2.2 Audits

Sydney Water undertakes internal audits of recalibration and verification results for trunk sewer models. The following audit reports were provided to the CRC:

- Technical Audit Report for West Hornsby STS Trunk Model; and
- Technical Audit Report for West Camden STS Trunk Model.

The audits are intended to be non-adversarial and are joint efforts between the modeller and auditor to identify practical improvements. Issues covered in the audits vary for the two reports, but include:

- Import/create trunk model;
- Dry weather flow calibration, eg use of all available gauges, flows, development during calibration period, changes in pump operation;
- Wet weather flow calibration, eg use of all available gauges, rainfall data, leakage, SPS operations, friction factors, overflow points;
- Model verification;
- Anomaly resolution;
- Benchmark model comparison;
- Report preparation; and
- Comments on gauge anomaly resolution and modeller responsibility.

The audit reports have addressed the main issues described in Quality Reports SSEPQP003_001 and SSEPQP003_002. It is recommended that the comments and recommendations made by the CRC in this report should also be considered for inclusion in the auditing procedure.

The CRC encourages the continued use of internal auditing and recommends that the auditors take account of the recommendations made in this report.

3.3 Appropriateness of the Proposed Performance Acceptance Criteria Used for Re-Calibration of Trunk Models

PRP 101.1 requires that "the Licensee must develop a set of performance indicators for comparing the predictions of the hydraulic sewer system model with the data from the reticulation sewer gauge network operated by or on behalf of the licensee. The licensee must develop a set of performance acceptance criteria for the hydraulic sewer system model based on the indicators. The indicators and

criteria must be applicable to all of the sewage treatment system specific models developed in 101.3 and the range of sewer flows in these systems".

The dry and wet weather calibration methodology for hydraulic sewer models and the statistical assessment of calibration results are respectively provided in:

- Report SSEPQP003_002 "Trunk Sewerage System Model Calibrations and Verification Procedure"; and
- SWAGMAN manual.

3.3.1 Performance Indicators

Sydney Water is using the following three performance indicators for recalibrating the trunk sewer models:

- Level above pipe invert;
- Sewer flow; and
- Overflow Incidence Index.

Outputs of the MOUSE trunk sewer models are water levels and flows at each point in the network at each time step. Field monitoring of sewage flows measures level and velocity. Flows are calculated from these two measurements. The measurement of level and velocity is well understood and relatively simple and accurate, assuming that flow gauges are adequately calibrated for all flows.

The CRC considers that pipe level and flow are appropriate performance indicators for the trunk sewer models because corresponding measured and model results can be obtained and compared. Furthermore, these indicators influence the behaviour of sewer networks and are fundamental to quantifying the occurrence, duration and volumes of sewer overflows.

The Overflow Incidence Index is defined as "the probability of the model predicting an overflow incidence when the measurements indicate an overflow incident" (refer to Sydney Water report PRP 101.1. System Model Performance Indicators).

In other words, this indicator compares the measured and model pipe level results as a function of time. If there is perfect agreement between the measured and model results for the time when the threshold level in the pipe (ie the level above which overflows occur) is exceeded, the Overflow Incidence Index would equal "1". Conversely, no agreement between the measured and modelled results would provide an Overflow Incidence Index of "0".

The Overflow Incidence Index is calculated according to the following equation:

Overflow Incidence Index = A/B

where: A= duration of overflow period when measured and model results overlap; and

B = duration of overflow as predicted by the model.

The CRC considers that in principal the Overflow Incidence Index is a sound performance indicator because it provides a measure of a model's ability to simulate the occurrence of overflows. The ability to simulate overflows is considered to be a major requirement for the trunk sewer models. However, it should only be used if the models have been demonstrated to be unbiased in terms of magnitude and time.

The CRC also has a concern about the method used by Sydney Water to calculate the Overflow Incidence Index. It is considered that the above equation is inconsistent with the previous definition of Overflow Incidence Index.

The definition describes overflows in terms of measurements that indicate an overflow incident. This has been interpreted as referring to field measurements and not model measurements. The equation calculates overflows in terms of duration of overflow as predicted by the model. Irrespective of the CRC's interpretation of "measurements" in the above definition of the Overflow Incidence Index, it is considered that this index should be calculated in terms of field measurements and not modelling results. Field measurements reflect actual occurrences and are not subject to modelling errors.

Several of the presentations indicated that there were inadequate data to calculate Overflow Incidence Index values. Therefore, in view of data limitations and the calculation method, the Overflow Incidence Index in its present form should not be used as a primary recalibration parameter. It is considered that models have good predictive capability for overflows if they pass the bias tests.

It is recommended that Sydney Water should continue to use the following two performance indicators for calibrating the trunk sewer models: level above pipe invert and sewer flow.

The Overflow Incidence Index should not be used in its present form as a primary recalibration parameter. Its method of calculation should be revised. It should then be used to confirm a models capability for predicting the occurrence and duration of overflows.

3.3.2 Performance Acceptance Criteria

Sydney Water has adopted the following performance acceptance criteria for calibrating the trunk sewer models. Models are required to pass all of these criteria in order to be considered to be calibrated.

- Pipe levels and flows should have no significant (95% confidence interval) temporal bias. Temporal bias is estimated by plotting residual (ie the difference between corresponding measured and model results) versus time.

- Pipe levels and flows should have no significant (95% confidence interval) magnitude bias. Magnitude bias is estimated by plotting residual (ie the difference between corresponding measured and model results) versus the average of model and gauge results.

- There is considered to be no bias if differences between measured and modelled levels and flows are less than 10 mm or 5% of Average Dry Weather Flow (ADWF), respectively, irrespective of the statistical results.

- The minimum value of the Pearson Correlation Coefficient (reported as the r^2 value) for corresponding measured and model level and flow data is 0.75. This value was chosen because measurement and modelling errors could collectively explain 20% to 25% of the total random variation. Therefore, the model should explain the remaining 75% to 80% random error.

- The minimum acceptable value for the Overflow Incidence Index is 0.75 using data periods of at least three months that include at least three significant overflows.

The two previous CRCs concluded that the statistical acceptance criteria are statistically robust because they measure both bias and random variability and include all relevant sources of error. Pearson Correlation Coefficient is useful as a measure of a model's predictive capability if it has no bias.

This CRC confirms these conclusions and the use of SWAGMAN to undertake the statistical acceptance tests.

However, this CRC has the following comments concerning the way in which the acceptance criteria are calculated and used:

- It is not clear why Sydney Water has concluded that a model needs to pass all of the acceptance criteria in order to be considered to be calibrated. The CRC considers that the models should be unbiased and should have the capability to correctly predict the occurrences, durations and volumes of overflows. Therefore calibrated models should ideally pass the two bias tests and the r^2 test.

It was noted that some of the trunk sewer models, for example the West Hornsby model, passed the two bias tests but not the r^2 test. It was concluded that the model had not been recalibrated satisfactorily.

However, it can be concluded that a model reproduces the occurrence of overflows in terms of magnitude and time if it passes the two bias tests (assuming that the flow gauges have been calibrated for all flows), irrespective of the r^2 value. It should be noted that the two bias tests are non-parametric tests, ie they do not assume a particular distribution of data, whereas the r^2 test assumes that the data are normally distributed. A lower r^2 value may therefore be the result of data distribution and may not be a true reflection of a model's predictive capability.

It is considered that the r^2 test should not be used as a primary performance indicator unless it can be demonstrated that the data are normally or approximately normally distributed.

The Overflow Incidence Index should not be used as a calibration variable, as discussed above.

The CRC recommends that the two bias tests should be the primary performance acceptance criteria.

The r^2 test should only be used if it can be demonstrated that the data are normally or approximately normally distributed.

- The primary purpose of the trunk sewer models is to simulate wet weather overflows. Therefore, the main objective of the calibration procedure should be to ensure that the models simulate wet weather flows satisfactorily. Although it is acknowledged that the models should be properly set up for dry weather conditions, their purpose is not to simulate dry weather conditions.

  The CRC is concerned that all modelling results, ie dry and wet weather results, are used for statistical verification of wet weather model recalibration. There are considerably more dry weather data than wet weather data. Therefore the dry weather data could "swamp" the wet weather data and have a major influence on the statistical calibration results. One solution would be to only use wet weather data for calibration purposes, although it is recognised that the pass criteria may need to be revised because of the inherently greater scatter of wet weather data compared to dry weather data. It is understood that SWAGMAN has the capability to only analyse parts of pipe flow, such as high flow data.

  The use of wet weather data for model calibration would require that sewer flow and level gauges are calibrated for high flows so that good

calibration data are obtained. The issue of gauge calibration at high flows is discussed below.

The CRC recommends that the calibration protocol should be revised to separately use dry and wet weather data for statistical verification of recalibration instead of data for all flow conditions, as is current practice.

- The two previous CRCs suggested that non-statistical "common-sense" criteria should be used in addition to statistical criteria for calibrating the models. This CRC notes that statistical performance criteria should be regarded as a supplement to good modelling practice and not be regarded as an end result in themselves. Good modelling practice requires modellers to adequately understand the configuration and performance of the systems being modelled.

  One of the performance acceptance criteria is that the model results are unbiased if differences between measured and modelled levels and flows are less than 10 mm or 5% of ADWF, respectively. This is a non-statistical criterion that requires modellers to review the data being statistically analysed.

  Some of the presentations gave the impression that modellers were applying the statistical tests and accepting the results without adequately understanding the causes and significances of inconsistencies between model and measured data. SWAGMAN provides the capability of plotting measured and model data as well as undertaking statistical analyses. The use of this capability should be encouraged to enable modellers to obtain improved understanding of the data and the causes of disagreements between measured and modelled data before applying the statistical tests.

  The CRC reiterates the suggestion of previous CRCs that non-statistical "common-sense" criteria should be used in addition to statistical criteria for calibrating the models. Furthermore, measured, operating and modelled data should be plotted or otherwise reviewed before statistical analyses are undertaken. In other words, the acceptance criteria should be viewed as a supplement to good modelling practice, not a substitute.

- The possibility of biases being introduced because of the frequency of data sampling by SWAGMAN was described in the West Camden model recalibration report. SWAGMAN samples data every 15 minutes whereas the sewage pump station (SPS) turns on and off at intervals of seven minutes or less. Therefore, the SWAGMAN sampling frequency is not sufficient to reflect the range of flows at the SPS. The West Camden model report recommended that SWAGMAN should sample data at one minute intervals.

The CRC recommends that the sampling frequency of SWAGMAN be reviewed and adjusted as necessary for each trunk sewer model so that the full range of data are used.

3.4 Calibration Process for a Selection of Completed 1994 Trunk System Benchmark Models and Results for Available Completed Models

The driver for model recalibration is PRP 101.3 (Model Recalibration). The relevant clauses in this PRP for the purposes of this CRC are as follows:

"Following approval by the EPA of the model Re-calibration Protocol, the licensee must re-calibrate the hydraulic sewer model(s) for the premises to a standard of accuracy that, at a minimum, meets the approved performance acceptance criteria."

"Prior to convening the Criteria Review Committee under 101.4, the licensee must run the approved re-calibrated hydraulic model sewer system model(s) for the premises with the 10-year rainfall time series data used in the EISs to refine the existing system performance used in the EISs."

Specific questions for the CRC are as follows (refer **Table 1.1**).

3.4.1 Review Appropriateness of Steps Undertaken to Transfer Models to OACIS Platform, Undertake Statistical Tests and Verification of the 1994 Benchmark Models.

Transfer of Models to OACIS Platform

The OACIS platform includes routines for importing models and data and links together the following five software packages in order to integrate the usage and exchange of data required for sewerage planning:

- HYDSYS;
- MOUSE;
- ModAsset;
- Hydra; and
- SWAGMAN.

The data integration provided by OACIS facilitates the model build and calibration process.

It is understood that all of the 27 STS trunk sewer benchmark models have been transferred to the OACIS platform prior to recalibration. A satisfactorily calibrated model provides confidence that the transfer to the OACIS platform has been undertaken satisfactorily. An uncalibrated model requires that model parameters should be reviewed and revised as

necessary so that model results agree satisfactorily with corresponding measured results. Therefore, the recalibration process ensures that the transfer of the trunk sewer models to the OACIS platform has been undertaken satisfactorily.

Statistical Testing

The quality system described in SSEPQP003_002 "Trunk Sewerage System Model Calibrations and Verification Procedure" specifies the use of statistical tests for calibrating the truck sewer models. The SWAGMAN package is used to calculate the statistical indices specified in SSEPQP003_002.

The CRC is satisfied that the statistical requirements as specified in SSEPQP003_002 are being followed by the trunk sewer modellers. However, the CRC has concerns about the way in which the acceptance criteria are calculated and used, as discussed in **Section 3.3.2**.

Verification of 1994 Benchmark Models

The model recalibration/verification procedures are described in:

- SSEPQP003_001: Trunk Sewerage System Model Build Procedure; and
- SSEPQP003_002: Trunk Sewerage System Model Calibration and Verification Procedure.

Comments are made on these procedures in **Section 3.2**. The CRC recommendation that a bias test should be applied to the three water storages (surface zone, root zone and ground water) using the ten year rainfall time series should be noted.

The following eight STS benchmark models are being recalibrated for dry and wet weather flows and statistically verified:

- Mount Victoria;
- Bellambi;
- West Hornsby;
- St Marys;
- West Camden;
- Blackheath;
- Northern Suburbs; and
- Malabar/Southern Suburbs.

Detailed presentations were provided to the CRC for the West Hornsby and West Camden systems and overview presentations were provided for the other systems.

Recalibration/verification of these models is not completed. The process to date has identified issues that need to be addressed before the models can be considered to be satisfactorily recalibrated. However, the CRC considers that when the issues identified in the presentations and in this report have been addressed the models will have been recalibrated and verified as far as possible using the available data.

Several of the presenters commented on a variety of data issues. Much of the data used for recalibration and statistical verification are considered to be of inadequate quality and/or quantity. It is a widely held truism that calibration of any model is only as good as the calibration data that are available. The poor quality of much of the data collected during the 1980s and early 1990s suggests that the benchmark trunk sewer models should be revised with newer and improved data.

The CRC recommends that where inadequate data prevent successful benchmark model recalibration, Sydney Water should identify a more recent and improved period of calibration data and update the benchmark trunk sewer models with the newer and improved data.

However, Sydney Water would need to demonstrate that the sewerage system has not deteriorated during the time from the current benchmark model (1991) to the recalibrated model using the newer data in order for the EPA to accept the calibrated model using the newer data as the new benchmark model.

3.4.2 Do the Re-Calibrated 1994 Benchmark Models Now Meet the Specified Acceptance Criteria?

Twenty six of the 64 flow gauges in these eight STS models pass all of the performance acceptance tests. However, none of the recalibrated 1994 benchmark models meet all of the specified acceptance criteria.

It is noted that the above eight STS models are generally satisfactorily calibrated for dry weather flows. However, they are not fully calibrated for wet weather flows, particularly large storm events. The reasons for incomplete model calibration include the following:

Inadequate Rainfall Data across Catchments for the 10 Year (1985 to 1994) Time Series

Virtual rainfall gauges were created to better represent spatial variations across catchments. However, most of the sewer catchments do not have rain gauges located within their boundaries. Furthermore, only a few of the actual rainfall gauges have data for all of the 10 year (1985 to 1994) time series. Therefore, the virtual rainfall gauges in some of the models use identical data for long periods of the 10 year time series because they

include the few rain gauges with data for all or most of the 10 year period. This is considered to be a major issue because rainfall is the primary type of data required for wet weather modelling and is the major source of error in hydrological models.

The CRC recommends that more rain gauges should be installed. It considers that, as a minimum, each of the licence gauge locations should have a rain gauge.

Inadequate SPS Operating Data

It is important for modellers to have satisfactory SPS data so that they can build satisfactory models and interpret model results. This requires an understanding of system operations, as discussed previously.

There are several reasons for poor SPS data, including:

- gaps in the wet weather flow data due to the methodology for determining flows at pump stations based only on pump operations. To obtain improved assessment of wet weather flows, monitoring at SPSs could be supplemented, for example, by monitoring the well level at appropriate time increments or by including in-sewer flow gauges upstream of SPS wells;
- undocumented upgrades during the calibration period; and
- localised flooding.

The CRC considers that it is important for modellers to routinely communicate with sewerage system operators in order to obtain improved understanding of the sewerage systems being modelled.

The CRC considers that it is important to revise the monitoring undertaken at SPSs to ensure that all wet weather flow data are captured.

The CRC recommends that a procedure should be developed to record all SPS configuration and operational changes and to maintain a historical record of all such changes.

Inadequate Data from Sewer Gauges

The results from several sewer gauges were affected by nearby SPSs. For example, the West Camden Model Recalibration report discusses the difficulty of the model matching the hydrograph shape at Gauge 828002 because the nearby SPS 614 switches on and off very frequently. This problem was difficult to resolve because of lack of operating data for SPS 614.

The CRC recommends that sewer gauge locations should be reviewed and changed, if necessary, to avoid future influences of SPS on gauge and model results.

Another problem relates to the lack of gauge calibration for high flows. It is understood that the highest flow that has been calibrated at some gauges is at 70% of full pipe flow. However, some gauges have only been calibrated for low flows. The assumption that 70% full flow is representative of full pipe flow needs to be tested. It is highly unlikely that low flow calibrations are applicable to high flows. This would mean that the trunk models may not accurately predict wet weather overflows because they are not calibrated for the high flows at which these overflows occur. This was also a major concern of the previous CRC.

This CRC reiterates the concerns of the previous CRC regarding the lack of gauge calibration at high flows and recommends that future improvements to the high flow calibration of gauges and models should be investigated.

Insufficient Model Detail

Several of the models have upstream "virtual" nodes to replicate the combined storage, surcharge and overflow characteristics of upstream subcatchments. The West Camden model also had a virtual catchment upstream of gauge 806000 to simulate large storm events. The use of virtual nodes indicates the possibility of inadequate model detail and/or understanding of the systems being modelled.

The CRC considers that virtual nodes should be systematically minimised with subcatchment models or the geometry of each model should be extended as appropriate so that the proportion of the system represented by virtual nodes is minimised.

Another problem relates to phase differences between corresponding measured and modelled data. These differences could be caused by changes in population, and hence dry and wet weather flows, during the recalibration period for several of the models. However, for the Malabar/Southern Suburbs model, phase differences are believed to be mainly caused by the influence of the North Georges River system. There is generally inadequate data available to conclusively resolve the phase difference issues. There are no suitable gauge data available to resolve the phase difference in the Malabar/Southern Suburbs model and SPS on/off data are being used.

It is recommended that Sydney Water should ensure that the trunk sewer models are systematically augmented with SCAMP data to ensure that changes in population and operating changes are included in the models.

Another reason for phase differences between the model and measured results could be the number of grid points used in the models. All models are currently being run with three grid points between each chamber. It is understood that depths are calculated at the upstream and downstream grid points, and flows and velocities are calculated at the middle grid point. The flow gauges are generally located at the downstream grid points. If the upstream pipe is very long this could potentially introduce a

significant variation in the flow modelled at the middle grid point and the actual flow at the downstream grid point, in particular when the hydraulic grade line slope is different from the pipe slope.

The use of three grid points in long pipes leading to a steep slope (including a drop) could also artificially increase the "draw down" of the hydraulic grade line leading to a steeper slope or drop. This effectively increases the apparent pipe capacity of this section and could lead to an overall lowering of the hydraulic grade line for a significant section upstream, particularly at flow rates in excess of the real pipe capacity.

It is recommended that the spacing of the grid points, at least at the licence gauges, should be reviewed to minimise errors in modelled flows.

3.4.3 If not, have all steps been taken to calibrate the model given input data availability and accuracy?

This question has been answered above. In summary, recalibration/verification of these models is not completed. The process to date has identified issues that need to be addressed before the models can be considered to be satisfactorily recalibrated. However, the CRC considers that when the issues identified in the presentations and in this report have been addressed the models will have been recalibrated and verified as far as possible using the available data.

3.4.4 Are the actions identified by Sydney Water to improve these models appropriate?

Several actions have been identified by Sydney Water to improve model calibration, including:

- More detailed models;
- Confirmation of populations and population growth;
- Improved understanding of system, including hydraulics and flows;
- Improved SPS operating information, including wet well level data to be used for verifying modelled SPS performance;
- Flow gauge calibration at high flows;
- Ensure that flow gauges record high flow events accurately;
- Smaller time steps for data sampling by SWAGMAN;
- Installation of surcharge sensors at licence gauge sites;

Most of these actions are under way and should result in improved model calibration. The CRC also considers that the recommendations discussed above (refer **Sections 3.3** and **3.4**) will also need to be implemented for satisfactory model calibration and benchmarking.

Comments have been previously made in this report concerning the need for modellers to review raw data, ie levels, flows and other operating data, prior to statistical analyses and to communicate with sewerage system operators to obtain better understanding of STS operations.

It is also recommended that modellers review SCAMP data, including maintenance records, customer complaints and choke data, to obtain additional verification data.

Furthermore, it is strongly recommended that modellers regularly discuss problems, issues and successes with each other to obtain mutual support and maximise operational knowledge of the models.

It is possible that some models may not be able to be satisfactorily calibrated. Sydney Water did not present procedures that are used to deal with systems that appear not able to be calibrated. It is considered that such procedures are required.

The CRC strongly recommends that Sydney Water should develop a protocol for system models that appear not able to be recalibrated to the adopted performance acceptance criteria, as required in PRP 101.2.

3.5 The Proposed Model Re-Calibration Protocol Specified in Report PRP 101.2

The continued use of the trunk sewer system models will require them to be further developed to include physical changes in the sewerage system. PRP 101.2 requires Sydney Water to develop a generic Model Recalibration Protocol for the ongoing recalibration of the hydraulic sewer system models. Sydney Water has prepared the report PRP 101.2 "Generic Model Re-Calibration Protocol" in response to PRP 101.2. This report describes the generic recalibration under the following main headings:

1 Introduction

2 Trunk Sewerage System Model

3 Triggers for Re-calibration

4 Data Requirements for Re-calibration

5 Re-calibration Methodology

The models remain in calibration until physical changes occur in the system. Sydney Water proposes to test this assumption annually by comparing model results for level and flow with comparable data collected at licence gauges. Data from the immediate past year would be run through the model and the results compared to the original calibration acceptance criteria. It is proposed that the minimum wet weather calibration period would be three months and that this

period should contain at least three rainfall events (two to define fast and slow response parameters and a third to define system surcharge behaviour).

The report proposes that the primary trigger for recalibration would be a value of less than 0.65 for the r^2 value. Other reasons to update the model include changes to system geometry and the effect of leakage reduction works.

The protocol appears logical and practical, although it is a generic protocol and little specific detail is presented. The CRC has the following comments:

- As noted above, the issue of models that are unable to meet the adopted performance acceptance criteria has not been adequately addressed.

- It is not certain whether three months/three storm events will provide sufficient data for recalibration purposes.

- The adequacy of the primary trigger (a value of less than 0.65 for r^2) needs to be demonstrated. It is not clear why the trigger value for r^2 should be 0.65 instead of 0.75. The performance acceptance criteria specify that the r^2 value should be at least 0.75 for a model to be considered to be calibrated, as discussed in **Section 3.3.2**. Therefore, a value of less than 0.75 would indicate that the model is not calibrated and should be the trigger for recalibration.

  Furthermore, it is considered that the r^2 test should not be used as a primary performance indicator unless it can be demonstrated that the data are normally or approximately normally distributed. This is because the Pearson Correlation Coefficient is a parametric test and lower values of r^2 may therefore be the result of data distribution and may not be a true reflection of a model's predictive capability.

- Sydney Water should consider using the magnitude and temporal bias tests as the primary trigger for recalibration. These are non-parametric tests and are therefore not affected by data distribution. It can be concluded that a model reproduces the occurrence of overflows in terms of magnitude and time if it if passes the two bias tests (assuming that the flow gauges have been calibrated for all flows).

The CRC recommends that the adequacy of three months/three storm events for recalibration purposes needs to be demonstrated. The adequacy of the primary trigger (r^2) should also be demonstrated and revised as necessary.

3.6 Associated Model Re-Calibration Processes that are Being Implemented by Sydney Water

Sydney Water proposes to check the calibration of each of the 27 system trunk models annually and update as necessary. Annual cycles for undertaking the model recalibration process were described to the CRC. It is proposed to undertake the following activities each year:

- Obtain system data including new pipes, modifications to existing pipes, overflow weir level changes, SPS upgrades, SPS operating changes, population and sewage flow changes;

- Upgrade models to include the above system changes;

- Run the updated models to check calibration at licence gauge stations. Model results would be compared with the previous calender year gauge data using performance assessment criteria in PRP 101.1; and

- Re-benchmark models to check that STSs have not deteriorated.

The necessary processes for maintaining and updating model calibration were not covered in detail in the Sydney Water presentations to the CRC. The CRC suggests that this topic should be addressed at a later date when the issues and recommendations by this CRC, as presented in this report, have been addressed.

In principal the CRC agrees that the trunk sewer models should be maintained as calibrated models for sewer overflow licensing purposes. The CRC makes the following preliminary comments at this stage:

- Significant system changes should be identified for use as triggers to determine which models should be updated and recalibrated. Suitable triggers could include ADWF, customer complaints and incidences of overflows. It is suggested that models would not be considered for recalibration unless trigger values had changed significantly since the model was last revised.

- Licence annual returns are required for all 27 STSs each year within 60 days from 30 June for the prior year. Suitably skilled resources will need to be made available to meet the modelling requirements as specified in the STS licences. It is noted that Sydney Water may find it difficult to meet licence delivery dates for all STSs with existing resources.

4 Conclusions and Recommendations

4.1 Overall Findings of the CRC

The CRC was appreciative of Sydney Water's candour. It is acknowledged that building, calibrating and applying sewer models for simulating sewer overflows for licensing purposes is a learning exercise for all concerned. However, it is evident that Sydney Water and the EPA have a common will to ensure that the modelling process is successful.

The CRC also recognises the large extent of work that has been undertaken by Sydney Water since the last CRC.

However, the CRC has identified a number of issues that may impact on model recalibration and benchmarking, including the ability to meet performance acceptance criteria, high flow gauge calibration, the appropriate level of model detail and the adequacy of the data for benchmark model recalibration.

4.2 Specific Findings of the CRC

4.2.1 Review Actions Completed by Sydney Water Regarding Recommendations of the previous CRC

Significant progress has been made for all the recommendations that are relevant to this CRC (refer **Table 3.1)**.

4.2.2 Quality Plans

The content and implementation of the Quality Plans were generally considered to be satisfactory. The CRC supports the continued use of internal auditing and recommends that the auditors take account of the recommendations made in this report.

However, the CRC recommends the inclusion of the following procedures:

SSEPQP003_001

- *Inclusion of sufficient detail to ensure that the system is adequately represented and to minimise the use of virtual nodes and overflows;*
- *Specification of pipe lengths in simplified models;*
- *Inclusion of all relevant access chambers;*
- *Verification of simplification procedure of non-standard pipe shapes;*
- *Verification that all overflow points have been included in the trunk model;*
- *All anecdotal information has been obtained;*
- *For dealing with missing data;*

- *Logic checks; and*
- *Check or audit procedures that all relevant factors have been considered.*

SSEPQP003_002:

- *To ensure that the same Manning n value is used between adjacent gauge points;*
- *To deal with different Manning n values for two independent gauged links;*
- *Separate calibration of flow and Manning n values;*
- *Bias tests should be applied to the three water storages (surface zone, root zone and ground water) using the ten year rainfall time series. This analysis should be included as part of PRP 101.1 System Model Performance Indicators.*
- *An explicit procedure for wet weather flow calibration;*
- *The audit validation should include checks of all adopted hydrological process parameters, statistical bias tests of storages and a check that consultation with operators and field inspections has been undertaken.*

SSEPQP003_003:

Procedures in this Quality Plan should either be detailed as in the other Quality Plans or should refer to the other Quality Plans.

4.2.3 Appropriateness of the Proposed Performance Acceptance Criteria Used for Re-Calibration of Trunk Models

Performance Indicators

The CRC considers that pipe level and flow are appropriate performance indicators for the trunk sewer models because corresponding measured and model results can be obtained and compared. Although in principal the Overflow Incidence Index is a sound performance indicator because it provides a measure of a model's ability to simulate the occurrence of overflows, the CRC considers there are problems with its use as a calibration parameter in view of data limitations and the calculation method. Furthermore, it should only be used if the models have been demonstrated to be unbiased in terms of magnitude and time.

The CRC recommends that:

Sydney Water should continue to use the following two performance indicators for calibrating the trunk sewer models: level above pipe invert and sewer flow.

The Overflow Incidence Index should not be used in its present form as a primary calibration parameter. Its method of calculation should be revised. It should then be used to confirm a models capability for predicting the occurrence and duration of overflows.

Performance Acceptance Criteria

Sydney Water has nominated four performance acceptance criteria- magnitude and temporal bias tests, the Pearson Correlation Coefficient (reported as r^2) and the Overflow Incidence Index. It is not clear why Sydney Water has concluded that a model needs to pass all of the acceptance criteria in order to be recalibrated.

The two bias tests are non-parametric tests whereas the r^2 test assumes that the data are normally distributed. The CRC has identified issues with the use of the Overflow Incidence Index. It can be concluded that a model reproduces the occurrence of overflows in terms of magnitude and time if it passes the two bias tests (assuming that the flow gauges have been calibrated for all flows), irrespective of the r^2 value.

The CRC recommends that:

The two bias tests should be the primary performance acceptance criteria.

The r^2 test should only be used if it can be demonstrated that the data are normally or approximately normally distributed.

The calibration protocol should be revised to separately use dry and wet weather data for statistical verification of recalibration instead of the use of data for all flow conditions, as is current practice (to avoid the possibility of wet weather data being "swamped" by more numerous dry weather data).

*Non-statistical "common-sense" criteria should be used in addition to statistical criteria for calibrating the models (*The relevant non-statistical performance acceptance criteria are that the model results are unbiased if differences between measured and modelled levels and flows are less than 10 mm or 5% of ADWF, respectively).

Measured, operating and model data should be plotted or otherwise reviewed before statistical analyses are undertaken. In other words, the acceptance criteria should be viewed as a supplement to good modelling practice, not a substitute.

The sampling frequency of SWAGMAN be reviewed and adjusted as necessary for each trunk sewer model so that the full range of data are used.

4.2.4 Calibration Process for a Selection of Completed 1994 Trunk System Benchmark Models and Results for Available Completed Models

Review Appropriateness of Steps Undertaken to Transfer Models to OACIS Platform, Undertake Statistical Tests and Verification of the 1994 Benchmark Models.

All of the 27 STS trunk sewer benchmark models have been transferred to the OACIS platform. The recalibration process provides confidence that

the transfer of the trunk sewer model to the OACIS platform has been undertaken satisfactorily.

The CRC is satisfied that the statistical requirements as specified in SSEPQP003_002 are being followed by the trunk sewer modellers. However, the CRC has concerns about the way in which the acceptance criteria are calculated and used, as summarised above.

Eight STS benchmark models are being recalibrated for dry and wet weather flows and statistically verified. Recalibration/verification of these models is not completed. The CRC considers that when the issues identified in the presentations and in this report have been addressed the models will have been recalibrated and verified as far as possible using the available data.

Several of the model presentations indicated that data used for recalibration and statistical verification are considered to be of inadequate quality and/or quantity.

The CRC recommends that where inadequate data prevent successful benchmark model recalibration, Sydney Water should identify a more recent and improved period of calibration data and update the benchmark trunk sewer models with the newer and improved data.

However, Sydney Water would need to demonstrate that the sewerage system has not deteriorated during the time from the current benchmark model (1991) to the recalibrated model using the newer data in order for the EPA to accept the calibrated model using the newer data as the new benchmark model.

Do the Re-Calibrated 1994 Benchmark Models Now Meet the Specified Acceptance Criteria?

Twenty six of the 64 flow gauges in these eight STS models pass all of the performance acceptance tests. However, none of the recalibrated 1994 benchmark models meet all of the specified acceptance criteria.

The reasons for incomplete model calibration include inadequate rainfall, SPS operating and sewer gauge data across catchments for the 10 year (1985 to 1994) time series, and insufficient model detail.

The CRC makes the following recommendations:

More rain gauges should be installed. It considers that, as a minimum, each of the licence gauge locations should have a rain gauge.

Future improvements to monitoring undertaken at SPSs to ensure that all wet weather flow data are captured.

SPS configuration and operational changes should be recorded and maintained as a historical record.

Sewer gauge locations should be reviewed and changed, if necessary, to avoid future influences of SPS on gauge and model results.

Future improvements to the high flow calibration of gauges and models should be investigated.

Virtual nodes should be systematically minimised with subcatchment models or the geometry of each model should be extended as appropriate.

Sydney Water should ensure that the trunk sewer models are systematically augmented with SCAMP data to ensure that changes in population and operating changes are included in the models.

The spacing of the grid points, at least at the licence gauges, should be reviewed to minimise the real time lag between the modelled flow and gauged flow.

Modellers should routinely communicate with sewerage system operators in order to obtain improved understanding of the sewer systems being modelled.

If not, have all steps been taken to calibrate the model given input data availability and accuracy?

The CRC considers that when the issues identified in the presentations and in this report have been addressed the models will have been recalibrated and verified as far as possible using the available data.

4.2.5 Are the actions identified by Sydney Water to improve these models appropriate?

Several actions have been identified by Sydney Water to improve model calibration. Most of these actions are under way and should result in improved model calibration. However, the CRC considers that the recommendations presented in this report should also be applied to obtain satisfactory model calibration.

Comments are made in this report concerning the need for modellers to review raw data, ie levels, flows and other operating data, prior to statistical analyses and to communicate with sewerage system operators to obtain better understanding of STS operations.

It is also recommended that modellers review SCAMP data, including maintenance records, customer complaints and choke data, to obtain additional verification data.

Furthermore, it is strongly recommended that modellers regularly discuss problems, issues and successes with each other to obtain mutual support and maximise operational knowledge of the models.

The CRC also strongly recommends that Sydney Water should develop a protocol for system models that appear not able to be recalibrated to the adopted performance acceptance criteria, as required in PRP 101.2.

4.2.6 The Proposed Model Re-Calibration Protocol Specified in Report PRP 101.2

The protocol appears logical and practical, although it is a generic protocol and little detail is presented. However as noted above, the issue of models that are unable to meet the adopted performance acceptance criteria has not been adequately addressed.

The CRC recommends that the adequacy of three months/three storm events for recalibration purposes needs to be demonstrated. The adequacy of the primary trigger (r^2) should also be demonstrated and revised as necessary.

4.2.7 Associated Model Re-Calibration Processes that are Being Implemented by Sydney Water

The necessary processes for maintaining and updating model calibration were not covered in detail in the Sydney Water presentations to the CRC. The CRC suggests that this topic should be addressed at a later date when the issues and recommendations by this CRC, as presented in this report, have been addressed.

In principal the CRC agrees that the trunk sewer models should be maintained as calibrated models for sewer overflow licensing purposes.

The CRC makes the following preliminary comments at this stage:

- Significant system changes should be identified for use as triggers to determine which models should be updated and recalibrated. Suitable triggers could include ADWF, customer complaints and incidences of overflows. It is suggested that models would not be considered for recalibration unless trigger values had changed significantly since the model was last revised.

- Suitably skilled resources will need to be made available to meet the modelling requirements as specified in the STS licences. It is noted that Sydney Water may find it difficult to meet licence delivery dates for all STSs with existing resources.

Attachment 8 Criteria Review Committee Report

SYDNEY WATER CORPORATION

INDEPENDENT CRITERIA REVIEW COMMITTEE
TO REVIEW
STS LICENCE MODELLING AND REPORTING
NOVEMBER 2025

Prepared by:

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DOCUMENT RELEASE INFORMATION

Client	Sydney Water Corporation
Project Name	Independent Criteria Review Committee to Review STS Modelling and Reporting
Document Title	Independent Criteria Review Committee to Review STS Modelling and Reporting Nov 2025
Revision Status	Final
Date	22 Dec 2025

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Abbreviations

ADWF	Average Dry Weather Flow
AM	Asset Management
CRC	Criteria Review Committee
DWF	Dry Weather Flow
EPA	NSW Environment Protection Authority
LTS	Longterm Time Series
FRC	Fast Response Component, used in MOUSENAM
PR	Peer Review
PRP	Pollution Reduction Program
PWWF	Peak Wet Weather Flow
r^2	Square of the Pearson Correlation Coefficient value
RDII	Rainfall Dependent Inflow/Infiltration
SCAMP	Sewerage Catchment Area Management Plan
SME	Subject Matter Expert
SPS	Sewage Pumping Station
SRC	Slow Response Component, used in MOUSENAM
STP	Sewage Treatment Plant
STS	Sewage Treatment System
SW	Sydney Water
TMR	Technical Management Review
WRRF	Water Resource Recovery Facility
WWF	Wet Weather Flow
WWOA	Wet Weather Overflow Abatement

1 Introduction

1.1 Background

Since 2000, Sydney Water has developed and been using computer models of the sewerage networks for each of its Sewage Treatment Systems (STSs), to assess the hydraulic and environmental performance of each system and report the findings to the EPA as part of the Annual Return Reporting process.

The sewerage system models are updated annually to reflect any physical or operational changes that have occurred over the reporting period. The updated models are then simulated with the rainfall record from the previous 12 months with the model results then compared with the recorded flow and depth data. If the model results fall within the required tolerances, the model is then used to assess the system with the benchmark 10-year rainfall time series. If the updated model falls outside of the required tolerances, the model is recalibrated prior to being simulated with the 10-year rainfall time series. All models are recalibrated and audited at least once every five years.

As part of the Annual Return Reporting, the environmental performance of each system is compared against the results from the benchmark year system performance, or the target system performance, to assess whether the system performance has deteriorated or improved over time.

The model simulated 'wet weather overflow performance' is compared to the limit condition or target system performance specified in the STS licence, to determine the compliant or non-compliant status of the system.

The current STS licences issued to Sydney Water, effective from 1 July 2024, for the period of 2025 to 2030, contain several requirements related to hydraulic sewer system models and their applications and reports. These are:

- Limit Condition, L7.1 – Hydraulic Sewer System Model
- Limit Condition, L.7.2 – Wet weather overflow limits
- Limit Condition, L.7.3 – Wet weather overflow improvement requirements that development of a wet weather overflow prioritisation methodology for the purpose of producing a baseline prioritisation profile
- Operating Condition, O4.8 (c) – No Deterioration clause for Networks
- Operating Condition, O4.9 – No Deterioration clause for WRRFs (Water Resources Recovery Facilities)
- Reporting Condition, R5.6 – Wet weather overflow abatement

A further requirement of the STS licences is that Sydney Water convenes an independent Criteria Review Committee (CRC) at least once every three Reporting Periods to review the methodology and findings of the Quality Systems audits and report the outcome of the review to the EPA.

Previous CRCs and one round of Independent Model audits on the STS models were conducted in May 2001, September 2001, May 2002, November 2002, May 2008, June 2013, May 2018 &

April 2022. An Independent Model Audit was conducted over 15th-16th October 2025 as a prelude to this year's CRC in November

1.2 STS Licence Requirements

The specific clauses of focus within the STS Licences for the period 1 July 2020 to 2025 pertaining to the CRC are:

L7.1 - Hydraulic Sewer System Model

a) The licensee must maintain a hydraulic sewer system model which has no temporal or magnitude bias in either flow volume or water levels at the licence gauges as referenced in the document titled "PRP101.1 System Model Performance Indicators, September 2000" and subsequent modifications made by the CRC.

b) The licensee must undertake an annual Quality System audit of the hydraulic sewer system model to determine if the model used during that reporting period meets the standards set out in condition L7.1 a).

c) The licensee must prepare a written report on each Quality System audit of any model used to assess sewage system wet weather overflow performance for the purpose of determining compliance with this licence. The report must also include the Pearson's correlation coefficient for the model used during the reporting period.

d) The licensee must provide a written report with each Annual Return on any Quality System audit of the hydraulic sewer system model stating the methodology and results of the audit.

e) The licensee must convene an independent Criteria Review Committee at least once every three Reporting Periods to review the methodology and findings of each of the Quality System audits.

f) The licensee must ensure that the independent Criteria Review Committee prepares a written report on the review required by condition L7.1 e).

g) The licensee must submit to the EPA a copy of each independent Criteria Review Committee report received by the licensee in a particular Reporting Period with the following Annual Sewage Treatment System Performance Report required by condition(s) at R5.6 of this licence.

This report fulfils the requirements of L7.1 e) to L7.1 g).

1.3 Objectives of Criteria Review Committee

The specific objectives of the 2025 CRC as identified by Sydney Water at the start of the CRC meeting were:

1. Compliance with L7.1 e)

Review Sydney Water's model rebuild and calibration processes to ensure continued compliance with performance acceptance criteria. This includes:

- Assessing the adequacy of the wastewater system model quality system.
- Reviewing the methodology and findings of recent Quality System audits.

2. Review of Integrated Catchment Modelling (ICM) approaches and evaluate Sydney Water's ICM framework, which aims to:

- Develop and improve base flow and quality models for wastewater, stormwater, and receiving waters.
- Integrate these models to simulate interactions through flow and level boundary conditions.

1.4 Scope

The scope provided by Sydney Water for the CRC was:

The CRC will assess the modelling and review processes by examining technical review reports and associated corrective or improvement actions. Detailed model evaluations are not required, as these have already been completed by Sydney Water's internal technical reviewers.

Through pre-reading and formal presentations, the CRC will evaluate and report on:

1. The alignment of the following documents with ISO 9000 requirements:
    - WWNP0007 – Model update, re-calibration and annual reporting procedure
    - WWNP0009 – Technical Management Review
    - NPSP0004 – Good modelling guidelines
2. Compliance with previous QMS Audit Findings
3. Progress and Outcomes of Model Rebuilds and Their Use in License Reporting.
4. Proposed changes to the base wastewater models and advice on any potential license implications that should be considered.

1.5 Key Stakeholder Expectations

In reviewing the modelling processes and performance assessments, it is essential to meet the expectations of both internal and external stakeholders.

The **internal stakeholders** include:

- Infrastructure Investment and Asset Performance (IIAP),
    - Environmental Regulatory
    - Waterway Health
    - Wastewater System Performance
- System Plans and Land Acquisition (SP&LA)
- Operational Technology – Hydrometric Services
- Customer Experience – Network Operations
- Engineering & Technical Support (ETS).

The **external stakeholders** identified include:

- NSW Environment Protection Authority (EPA)
- Department of Climate Change, Energy, the Environment and Water (DCCEEW)
- Local Councils

These stakeholders rely on the wastewater models and their outputs for a range of purposes, including:

- Ensuring regulatory compliance and environmental protection
- Supporting infrastructure planning and investment decisions
- Informing operational strategies and performance monitoring
- Engaging with the community and responding to development needs

1.6 Members of the Panel

The CRC Panel consisted of three independent experts with a broad mix of sewerage network system modelling, monitoring, planning, environmental modelling, system operations and Corporate Governance.

Mr Neil Moody (CRC Chairman)	Managing Director, Urban Water Solutions (Vic)
Ms Angela Dwyer	Principal, Beca HunterH2O
Mr Clint Cantrell	Managing Director, SCO Consulting, New Zealand.

The CRC Chairman, Mr Neil Moody, has been a CRC participant since 2001.

Ms Angela Dwyer, participated in the 2022 CRC and again provided many insightful observations during both the Audit and CRC.

Mr. Clint Cantrell has extensive international experience in wet weather programs throughout the USA, NZ and Australia and provided many nuanced observations and commentary in his first CRC. The CRC has benefited greatly from the perspectives of "fresh sets of eyes".

1.7 Agenda and Meeting Procedure

The CRC met on Monday 3rd and Tuesday 4th November 2025, in Room 4.01 and 4.02 at Sydney Water's Head Office, 1 Smith St, Parramatta. The agenda and presenters are shown below.

Monday 3rd November 2025

Time	Sessions	Topics	Presenters
9:30	1	Introductions	Wasif Elahi
9:45	2	Agenda / CRC conduct	Graham Orgill
10:00	3	CRC Objectives - License requirements	Graham Orgill
10:15	4	Previous CRC outcomes and Actions	Graham Orgill
10:30		**Morning Tea**	
11:00	5	Sydney Water's management systems frameworks	Iain McCrae
11:15	6	CAMMs - how compliances are tracked and reported	Ellie Robbie / Courtney Keep
11:30	7	Sewer and rain gauging & Data quality auditing processes	Chris Harris
11:45	8	Summary and progress of 2024/2025 modelling	Anwar Hoosain
12:00	9	Peer review and technical management review processes	Noor Hossain
12:15	10	Open forum – Discussions	All
12:30		**Lunch**	

13:15	11	Re-building Wastewater Network Models - Narrabeen	Aman Kidanemariam
13:30	12	Re-building Wastewater Network Models - West Middle Harbour	Hossein Samadi
13:45	13	Re-building Wastewater Network Models - Mid Parramatta	Farhana Noor
14:00	14	Re-building Wastewater Network Models - NSOOS_NST	Siming Gong
14:15	15	Open forum – Discussions	All
15:00		**Afternoon Tea**	
15:30	16	Panel Closed Session	
16:30	17	Day 1 Finishes	

Day 2 - Tuesday 4th November 2025

Time	Sessions	Topics	Presenters
9:00	18	CRC Panel closed session	
10:00		**Morning Tea**	
10:30	19	Integrated Catchment Modelling	Kaushal Kumandur
10:45	20	OACIS 3 -Widgets for Mike+	Aman Kidanemariam
11:00	21	Stormwater 1D/2D Model Development – Sydney CBD	Sadeq Zaman, Dong Le, Khang Nguyen
11:15	22	Receiving Water Models outputs for Risk Assessment	Pei Tillman
11:30	23	Modelling Road Map	Graham Orgill
11:45	24	Open forum - Discussions	All
12:30		**Lunch**	
13:00	25	CRC Panel closed session	
14:30	26	CRC de-briefing	CRC Members
15:30		**Afternoon Tea**	
16:00	27	CRC meeting Closed	Graham Orgill

1.8 Pre CRC Audit

In accord with Recommendation 05 from the 2022 CRC report an independent audit of 3 selected STS models and the application of the quality system was undertaken over the 15th and 16th October 2025. The Audit team was comprised of:

- Mr. Neil Moody, CRC Chairman and UWS Managing Director & Principal Wastewater Engineer
- Ms. Angela Dwyer, Beca HunterH2O, Principal Water Engineer
- Ms Maggie Goldie, Beca HunterH2O, HSEQ Manager/Facilitator

Engineering Modelling (EM) Manager Graham Orgill commenced proceedings with an overview of the major changes in team structure and composition that had been implemented since 2022. In particular, the clarification of the roles and responsibilities for the EM team with regards to Base and Growth Model custodianship.

A further major positive improvement since the 2022 CRC has been the expansion of detail in the larger STS systems that has resulted in the 23 STS models being expanded into 41 detailed WWCM models, all at SCAMP level of details.

The three models selected for review were agreed upon by the CRC Chairman and SW and covered the following small, mid-size and large STS systems:

- Narrabeen (part of the North Head system)
- Shellharbour
- Rouse Hill

The model Audits were well attended by the SW Engineering Modelling team, many of whom only had around 12 months' experience with SW's processes and systems.

Details of the outcomes from these "deep dive" audits will be addressed later in the report but overall, the audit team was impressed with the level of understanding displayed by the presenters and team members in attendance of the SW modelling systems and processes from the largely new team.

1.9 Presentation of CRC Findings

The following sections in this report have been broken into three categories:

- General findings and observations noted during the presentations.
- Specific findings with respect to the stated CRC objectives; and
- Consolidated findings with recommendations for improvements.

2 Comments On Presentations

2.1 Introduction

The presentations to the CRC were all made in PowerPoint format and digital copies were made available to the CRC Panel. The presentations were of a good quality; the presenters spoke knowledgeably and displayed interest and enthusiasm when discussing their areas of focus.

As has been the custom on previous CRCs, questions were raised by the CRC Panel during presentations that resulted in robust discussions between panel members, presenters and the members of Sydney Water's project team in the audience. The following sections detail the topic from each session with significant comments and questions raised during the presentations, together with a summary of discussions made in the CRC Panel closed sessions.

2.2 Session 1: Introductions

The opening presentation provided a general overview of the conduct of the CRC, Acknowledgement of Country, general housekeeping issues, the proposed agenda for the CRC, introductions of CRC participants, their roles and responsibilities.

CRC Panel Discussion and Comments

On review of the Agenda, the CRC Panel identified that some sessions may need additional time and advised that they were satisfied that there was sufficient time at the days end to allow additional session time if required.

2.3 Session 2-3: CRC Objectives, License Requirements and Strategy Overview

Summary

A comprehensive presentation was delivered by Engineering Modelling (EM) Senior Manager Mr Graham Orgill:

- Graham outlined the purpose and principles of the CRC and composition of the key panel members
- Graham demonstrated the key features of SW strategy for 2025-2035 and the complexities and challenges entailed to integrate and align many SW processes to achieve the end goal.

- To deliver the needs of the Strategy, a comprehensive resourcing plan was presented identifying the annual resourcing needs for the Engineering Modelling group from 2025 to 2030.
- Reframing the function of the EM group as the creators and custodians of all Base Engineering Models which then become a single source of truth for distribution to other users of models across the business has clarified the primary roles for the group.
- EM group also responsible for the development of Growth Area Models and STS license modelling and reporting.
- Clear distinction made between the function and responsibility for Base models and Scenario modelling.
- A key aspect of interest with the resourcing plan was the distinction between what modelling activities are designated as a Capital Expense and what activities are considered an Operational Expense.
- Michelle Cassidy presented an informative video demonstrating the overflow abatement progress over the past 9 years

CRC Panel Discussion and Comments

Panel overall very impressed with the breadth and depth of progress over the past 3 years since the last CRC in 2022, particularly with regards to the framing and clarification of the roles of the EM group and where it sits within the delivery of the broader Strategy.

Clear distinction between accountability and Authority.

Satisfied that the STS modelling aspect, which is the main driver for the CRC, is well addressed within the broader Strategy, particularly as the Base models will be the STS models used for reporting.

The panel was also very impressed by the efforts to capitalise certain aspects of model development and treating models as assets, which is industry leading and, in our opinion, is an example for other utilities to follow.

2.4 Session 4: Previous CRC Outcomes and Actions

Summary

SW reported on the actions undertaken in response to the recommendations from the 2022 CRC. The majority of recommendations have been addressed, or activities are in progress to address the identified issues.

Rec No.	2022 CRC Panel Comments/ Recommendations	
Rec01	Sydney Water to undertake an assessment of alternate hydraulic modelling software available in the market to replace MOUSE which is currently unsupported. Given the major modelling program transformation that is currently taking place in SW, adoption of the new software platform prior to finalisation of revised system performance benchmarks would be highly desirable. In addition to having similar hydraulic/hydrologic capability to Mouse, additional features to be considered in assessing alternate software platforms include: • Ability to explicitly incorporate pump curves and pressurised rising mains into the model. • Potential to incorporate and simulate sewage water quality parameters for the purpose of prioritising overflow abatement works based upon pollutant load in addition to volume and frequency considerations. Add on capability to import forecast rainfall data and undertake forecast simulations.	**In Progress** SW assessing alternative hydraulic modelling software. • Mike conversion widget for ICM • OACIS and ModAsset replacement • Modelling roadmap
Rec02	The CRC Panel fully support the transition of all models to the SCAMP level of detail acknowledging that this will result in the need to redefine and renegotiate system benchmark baselines.	**Completed** All models have been developed to SCAMP level of detail
Rec03	The CRC Panel supports the proposal to break up the larger STS systems into smaller subsystems for management and license reporting purposes, delineated where possible based upon the overflow receiving waters.	**Completed** Larger STS systems have been broken up into smaller subsystems
Rec04	The CRC Panel support the 3-stage targeted approach to address wet weather overflow abatement compliance and expect that following post rehabilitation monitoring that the program and approach will be refined over coming years	In progress
Rec05	The 2008, 2013 and 2018 CRCs identified the need	**Completed**

Rec No.	2022 CRC Panel Comments/ Recommendations	
	to engage suitably qualified experts that have been external to the license modelling process to undertake detailed audits/reviews of the STS models. This recommendation is reiterated from this CRC.	Independent audit of wastewater models undertaken in October 2025 Plan to undertake audit every 3 years
Rec06	Resourcing: The CRC Panel recommends that SW evaluates future staffing levels required to support the increased requirements for model update and calibration as all models transition to SCAMP level models.	**Completed** Team size has increased from 7 to over 25 with 4 defined streams. Roles and responsibilities clearly defined The expanded team has allowed SW to deliver the STS modelling internally
Rec07	The CRC Panel fully encourages SW to continue the development of stormwater models to provide ERS boundary conditions to support the wastewater modelling program.	**In Progress** ICM project is progressing
Rec08	The CRC Panel supports Sydney Water in the need to review system performance benchmarks, particularly once all licensing models are created to the SCAMP level of detail. In addition to redefining the baseline system performance based upon the frequency and volume of overflows predicted by the detailed models, establishment and definition of benchmark overflow "event periods" to resolve the current anomaly whereby a significant reduction in overflow volume could result in one long "overflow incident" being redefined as two or more overflow events.	**In Progress** Discussions have been held with EPA with regards to revised baseline STS model performance
Rec09	The CRC Panel encourages further refinement of the processes involved in creating SPS inflow/outflow data at each SPS, thus providing additional potential model calibration points.	**Not yet started**
Rec10	The CRC Panel supports the strategic sewer gauging review and recommends a staged implementation over several years.	**In Progress/ BAU** More gauging has been implemented as part of ICM project.

CRC Panel Discussion and Comments

Of the 10 recommendations from 2022, the only items not covered clearly over the course of the CRC were items 8 and 9. SW advised that discussions had been held with EPA with regards to the revised baseline STS model performance associated with bringing all STS models up to SCAMP level of detail.

2.5 Session 5: Sydney Waters Management System Framework

Summary

- Mr Iain McCrae provided an overview SWs quality management system
- External 2025 audit of SW quality systems resulted in zero non-conformances and 5 opportunities for improvement.
- Overview provided of internal processes to provide management system governance.
- Information mapping shed a lot of light on where duplication was occurring, and where improvements could be made.
- SW moving toward an Integrated Management System (IMS) which will reduce duplication of controls/processes and provide a single source of truth and improve risk and compliance outcomes.

CRC Panel Discussion and Comments

Panel satisfied with the corporate system in place and concur with the transition to an IMS to simplify and reduce duplication of systems and processes and to further mitigate risk around development, refinement and use of models to inform compliance reporting and capital investment planning.

2.6 Session 6: CAMMs

Summary

- Ms Ellie Robbie and Courtney Keep provided an overview of the CAMMs system and how it is used to record and report on EPL compliance.
- CAMMs used to assist with review and sign off for the 2024-25 EPL Annual Returns.
- Demonstration of the process flow from incident initiation through compliance status, review and obligation acceptance to lodgement with EPA

CRC Panel Discussion and Comments

Panel satisfied with the overview provided that the CAMMs system seems to adequately track the progress of reported incidents from initiation through to EPA submittal

2.7 Session 7: Sewer and Rain Gauging & Data Quality Auditing Processes

Summary

Mr Chris Harris, SW Hydrometric Services (HS) Manager, presented on the range of services provided by the SW Hydrometric services group including gauge deployment, calibration, data collection, data processing and delivery with the overarching quality controls embedded within their processes.

These systems and processes are well established and have been reviewed in detail in previous CRC's and are considered to be of a high standard.

- The HS group currently maintains over 1,100 gauges at present as well as 19,000 IoT gauges.
- Existing IoT devices are relatively simple under/over trigger level however new generation devices will which provide real time level data. It is planned to install the new devices in MHs with ERSs.
- There are 150 level gauges sited in ERS's that have associated ratings tables to compute flows assuming free discharge into the receiving water.
- HS group looking at Power BI dashboards and incorporating machine learning to improve detection of anomalies.
- Modeller issued queries treated as an anomaly
- EM team have been involved in monitoring site visits with HS team to gain broader understanding of challenges associated with collecting data from sewers in urbanised areas.
- Since last CRC a new role has been created within HS for dedicated hydrometric data specialist.
- ERS investigations ongoing as part of ongoing source control program

CRC Panel Discussion and Comments

The processes in place to collect, review and quality control data are of a high standard and the culture to continuously improve the processes and delivery of data is commendable.

Potential issue for overestimation of flows calculated from ERSs to receiving waterway identified with the working assumption of a free outfall from the ERS. Combined system modelling will assist in identifying ERS that have high potential for being submerged from the storm water system. Inclusion of additional depth sensors in storm water system may be warranted.

IoT data not currently readily accessible to EM team. Consider mechanisms for making this data more broadly available.

Panel commend the increased interaction between EM and HS staff particularly with regard to site visits to assess suitability of gauging locations.

The panel also recommends careful consideration of a future scenario where all ERSs are monitored and reported on in real time, including community access to this data. This is largely based on the recent experience in the UK, which has resulted in some unintended consequences in terms of managing perceptions and expectations on how benefits are assessed beyond simple spill frequency and spill duration metrics. Also, will IoT devices located at all ERSs result in some deeper assessments of model accuracy in terms of overflow frequency and duration predictions?

2.8 Session 8: Summary and Progress of 2024/25 Modelling

Summary

Mr Anwar Hoosain delivered an informative presentation on the significant changes that have been made to the License modelling program since the last CRC in 2022.

SW have transitioned from managing 224 SCAMP models, which fundamentally included all pipes 225 mm and above, and 23 STS trunk models to now managing and maintaining 41 Wastewater Catchment Models (WWCMS) which are all constructed to SCAMP level of detail. The WWCMS will now provide a single point of truth and will be used for license reporting, planning and system analysis.

To achieve this level of detail, and maintain reasonable model simulation times, it has been necessary to break down the larger STS systems, in particular Malabar and North Head, into a number of catchment models generally using long term gauges as boundary conditions.

Statistics provided in the presentation illustrated that the 9 WWCMs that now comprise the Malabar system have resulted in a major increase in the length of sewer explicitly modelled from 586 Km up to 2348 Km, with modelled ERSs increased from 467 to 1,112 and SPs from 50 to 163.

One concern discussed at the last CRC, that may have arisen from this process, was the potential need to redefine the base overflow targets when the more detailed models were simulated with the LTS. The presented system performance data comparing the former 2022 trunk model of the North Head system with the 7 WWCMs that now comprise the North Head system showed a very similar overflow frequency from the 10-year LTS.

CRC Panel Discussion and Comments

Transitioning to the SCAMP level of detail for all WWCM's and maintaining these models as the single point of truth for STS reporting, system analysis and planning is a very welcome step change.

With all WWCMs now at the same level of SCAMP will provide a greater level of confidence of the modelled system performance higher up in the catchments and provides a consistency of model across the whole service area.

In addition to the efficiencies gained with this process, the inclusion of all constructed ERS into the models, together with all significant pumping stations, has resolved a number of long-term queries associated with the larger, heavily simplified STS trunk models and the use of virtual overflows to represent unmodelled ERSs.

2.9 Session 9: Peer Review and Technical Management Review Processes

Summary

Mr Noor Hossain presented on the systems in place to fulfill the section L7.1b requirements from the EPL to undertake an annual Quality System audit of each hydraulic sewer model to determine whether the model fulfils the requirements of L7.1a in the EPL.

These processes have continuously evolved over the 25-year life of the program and are well known to the CRC panel and considered to be robust and mature.

The review is a two-part process:

1. Peer review – undertaken within the modelling team
2. Technical Management Review (TMR) – external to the modelling team but within SW.

The QA process for Peer Review was demonstrated with a flow chart based on the verification plan WWNP00007.01.

The TMR QA process was also described in detail and an example of a complete review for the Mid Parramatta WWMC was provided. The 3 stages of the TMR process were described in detail and the completed TMR for the West Camden model was demonstrated.

There are currently 4 experienced TMR reviewers on the panel, 2 from the EM team and 2 from Planning.

CRC Panel Discussion and Comments

- The Peer Review and TMR processes are generally robust, have matured over the past 25 years and are well understood by SW team members and the CRC.
- Based upon the information presented, the CRC is generally satisfied with the application of these reviews and processes.

- The CRC panel has noted a subtle change in the verification process since the last CRC. Previously it was understood that all STS models, following the annual update, were simulated with the previous year's rainfall and a verification comparison made with data from the License gauges. In recent years it appears that STS models that haven't triggered a need for recalibration due to population growth, network changes etc have not undergone verification simulations.
- While it is understood by the Panel that not every model can be recalibrated each year, the Panel considers it necessary to undertake the verification simulations annually and to make the verification results available to downstream users of the model, even if out of calibration.
- Going forward the Panel recommends that additional resources be recruited / trained up to expand the pool of qualified reviewers to enable a smooth transition.

2.10 Sessions 11-14: Rebuilding Wastewater Catchment Models North Head System

Summary

The following sessions comprised presentations on the building and calibration of four of the WWCMs that are part of the North Head system. Due to the commonality between these presentations, the following section provides a few key details for each specific WWCM and a range of common observations.

The modellers who have developed these WWCMs and presented on their work are all new to the CRC panel each with approximately 12 months experience with SW and were all involved in the October 2025 detailed Audit sessions. During the CRC and detailed Audit sessions it was apparent that the new resources have assimilated well and have a good understanding of the OACIS system and underlying processes. Some of detailed commentary in the following is drawn from the findings from the October 2025 Audit but is consistent with what was observed at the CRC.

Narrabeen System

- The Narrabeen system WWCM explicitly contains more than double the length of pipe contained in the former STS model for this area.
- A good level of calibration was generally achieved for flows however there were a few examples presented at gauge 820113 where it appears that either the depth sensor data was truncated during two of the larger events or that there may be a manhole overflowing upstream.
- A challenging aspect to model this system is the operation of the 18 ML storage tank at SU0163. Real Time Control (RTC) rules have been developed based upon the "normal" operation of this facility; however, it is apparent that on some occasions there has been operator intervention to modify the actual operation during wet weather events. The

MOUSE modelling software is unable to readily accommodate these “ad hoc” changes to system operation.

- During the Audit review it was identified that the calibration was undertaken using the “virtual” rain gauge assignation used for the previous STS model and in particular the LTS simulations used to establish system performance. In the period between the Audit and the CRC this anomaly was rectified with subcatchments reassigned to the available calibration rain gauges using the Thiessen polygon method.
- Overall, a satisfactory level of calibration was achieved.

West Middle Harbour System

- The West Middle Harbour WWCM has had a dramatic increase in the extent of assets explicitly modelled. The WWCM includes 297 km of sewer, up from 34 km in the STS trunk model with the number of ERS increased to 150 from 35 in the STS model.
- While a satisfactory calibration was achieved some anomalies were identified when comparing the model results with the observed data between small, median and large events with “flat topping” occurring at some monitor sites. This generally indicates an overflowing upstream manhole or unidentified ERS and needs to be explicitly modelled to ensure hydraulic robustness during these large events.
- The need for additional gauging identified at 3 locations.

Mid Parramatta System

- The Mid Parramatta WWCM has had a relatively minor increase in the extent of assets explicitly modelled. The WWCM includes 113 km of sewer, up from 96 km in the STS trunk model with the number of ERS increased to 93 from 79 in the STS model.
- Given its position in the North Head network, the Mid Parramatta system has 3 major upstream inflows, 3 minor inflows and a downstream boundary condition at 820011.
- Additional gauging required to better quantify all the upstream inflows, particularly in West Ryde area.
- Modelling the complex siphonic overflows challenging for any modeller and a good effort from a relatively new modeller.

NSOOS NST System

- The NSOOS NST WWCM has had a significant increase in the extent of assets explicitly modelled. The WWCM includes 488 km of sewer, up from 211 km in the STS trunk model with the number of ERS increased to 248 from 144 in the STS model as well as the number of pumping stations increased to 51 from 30.

- The NSOOS NST is the most downstream of the WWCMs and receives inflows from the Mid Parramatta, Lane Cove, West Middle Harbour and Narrabeen WWCMs with 8 boundary inflow locations and the outfall at Manly.
- The land use in this WWCM contains major commercial centres in North Sydney, Artarmon and Chatswood as well as popular tourist destinations including Manly and South Curl Curl and hence there is noticeable seasonal fluctuations in flows at some gauges.
- A suggestion was made from the modeller to create diurnal flow patterns for mixed land use areas to improve the DWF representation. From extensive past experience with these issues the Panel suggested that more detailed subcatchments be delineated in these mixed areas to differentiate between the different land use types when significant.
- Approximately 75% of the flows in this catchment are inflows from upstream WWCMs and hence variations in flow patterns, minor inaccuracies in flow data (even within specified accuracy limits) and dropouts from the observed inflows will all impact the performance of this WWCM.
- Given the challenges with this WWCM with inflow sources a satisfactory level of calibration was achieved.
- As identified by the modeller, due to the complexities and dependency on high quality inflow data at the boundaries there is an ongoing need to refine the cross-team investigation of the boundary inflows and further collaboration with the Hydrometrics data management team.

Shellharbour System – (Reviewed during October 2025 Audit)

The Shellharbour WWCM is comprised of 3 former SCAMPS and was interrogated during the October 2025 Audit. This WWCM was selected for detailed review as there have been issues identified in this system during previous CRC reviews, in particular involving the operation of the major SPSs which control the flows in the network. Key findings:

- SW team members demonstrated a high level of understanding of the OACIS system and how to access supplemental data on historical pumping station performance data from IICATS.
- The historical SPS data from IICATS clearly demonstrated that the wet weather operation of the major SPSs have frequent operator intervention with regards to pump speeds and operation. This type of ad hoc operational change is unable to be modelled with limitations of the MOUSE RTC facility.
- Given the significant growth occurring upstream in this system, there appears to be opportunities to improve wet weather system performance through optimised use of available storages in the network and modifying pump operations to best manage wet weather flows.

CRC Panel Discussion and Comments

Overall, the Panel was impressed with the quality of the presentations and the understanding of the systems performance demonstrated by the presenters. The following comments cover a few systemic matters with have come to light with the transition to the WWCM models and other matters that will need to be addressed with the selection of the future modelling platform.

- A common theme across all of these WWCMs was the need for additional gauges, particularly at boundaries, and/or the need to refine WWCM catchment extents, understanding the challenges with the existing OACIS processes with geographically non-contiguous catchment areas.
- The future modelling platform needs to have capability of modelling ad hoc changes to RTC rules at pumping stations, storages and other facilities that are operator regulated.
- The "flat topping" observed in some of the flow and depth data comparisons tend to indicate that upstream or downstream manholes, or unidentified ERS, are activating during some of the larger events. The new modelling platform needs to have the capability for all manholes to overflow when the water level reaches the cover level by default with the ability to seal those manholes in the model that are known to have been bolted down.
- Further interrogation of data in consultation with the Hydrometrics group required to distinguish between gauge sites that have "capped out" versus upstream or downstream manholes that are overflowing and not represented in the model.
- As demonstrated with the version of the Narrabeen model presented at the Audit compared with the version at the CRC, there is the need to distinguish between rain gauge assignation for each subcatchment during calibration / verification and the virtual rain gauge assignment associated with the LTS simulations.

2.11 Session18: Engineering Modelling Road Map

Summary

Mr Kaushal Kumandur delivered a presentation on the comprehensive body of work undertaken by SW to define "where are we" and "where do we need to head" and what processes and systems get carried forward and what needs to be refined, updated or replaced, looking at the entire modelling processes undertaken by SW.

Following canvassing of reflections and opportunities within the EM team, key takeaways were:

- Resourcing constraints
- Progression within team/ career and skills
- Digital experience

The recent realignment of the group has largely addressed the first two areas of concern. The group has grown from 7 to 20+ over the past 2 years and with the new structure there are multiple layers of seniority and opportunities for new team members to learn from Senior/Principals, clear lines of responsibility with managers leading different streams as well as pathways for professional progression.

Progress with Digital is underway and the team have engaged with Digital to see what can be done to uplift the modelling processes.

Key modelling requirements have been streamed into 4 primary channels:

- Data management
- Technology Development
- Modelling Process Improvements and
- Model outputs

The presentation went into detail covering the Enterprise Capabilities and Functional Requirements for the Engineering Modelling cycle with defined needs, assessment of current status and desired Future State.

SW has identified the importance to develop a comprehensive plan that will work from end to end rather than looking at functional requirements in a piecemeal fashion.

From the perspective of a business feasibility lens, it is apparent that SW can't deliver all the functional requirements at once. The priority and risk of the range of fundamental modelling requirements was assessed, and the highest risk items were generally data related.

The known challenges of upgrading existing systems include but are not limited to:

- ModAsset – written in Delphi, 32 bit with unsupported underlying database
- MOUSE – DHI simulation engine has been unsupported for a number of years
- OACIS – Bespoke technology, SW unable to support due to inadequate Code documentation and incompatibility with 64-bit architecture.

SW not just looking at software capability to do the modelling they need but also through a digital and commercial lens.

A draft high level roadmap was presented identifying the priorities for the Modelling Strategy over the next 5 years, however due to the criticality of OACIS it may need to be dealt with in advance of its Needs Assessment Business Case (NABC).

The team is currently working with vendors to discuss the functional requirements with the intention of going to the market by mid-2027. SW is adopting a holistic approach, moving away from user preference and instead focusing on functional requirements.

CRC Panel Discussion and Comments

The Panel was pleased to see that there are solid plans in place to upgrade and replace existing systems, as this was viewed as one of the critical items to address from the previous CRC. The early engagement with the market demonstrates the commitment to replacing the aging systems with products that meet all the functional requirements of the 200+ users of the models.

2.12 Session 19: Integrated Catchment Modelling

Summary

Mr Kaushal Kumandur presented on the progress of SWs Integrated Catchment Modelling program.

A key driver for the ICM is to be able to better quantify and compare the impact of the overflows from the sewerage system into the receiving waters, and the subsequent prioritisation of engineered solutions.

The process is currently a “soft integration”, with stormwater and receiving water models run independently from the sewerage system models. Time series outputs from the stormwater models provide tail water boundary conditions that are applied to the downstream outlets for each ERS.

As part of this process, ERSs that are identified as being prone to elevated water levels in the receiving waterway, particularly those exceeding ERS levels, are being investigated and faulty flap valves etc being remediated.

Details were provided of the flow monitoring and water quality sampling programs proposed for the sewerage system, stormwater network and receiving waterways.

The program of works required to effect delivery of the prioritised IPART submission by 2029 was demonstrated to enable source control works to be completed over the 2030-35 period.

GHD, DWS and UNSW have been contracted to develop the new models for this program and works have commenced on the hydraulic model component.

CRC Panel Discussion and Comments

The program appears to be well thought out with challenging but achievable timelines.

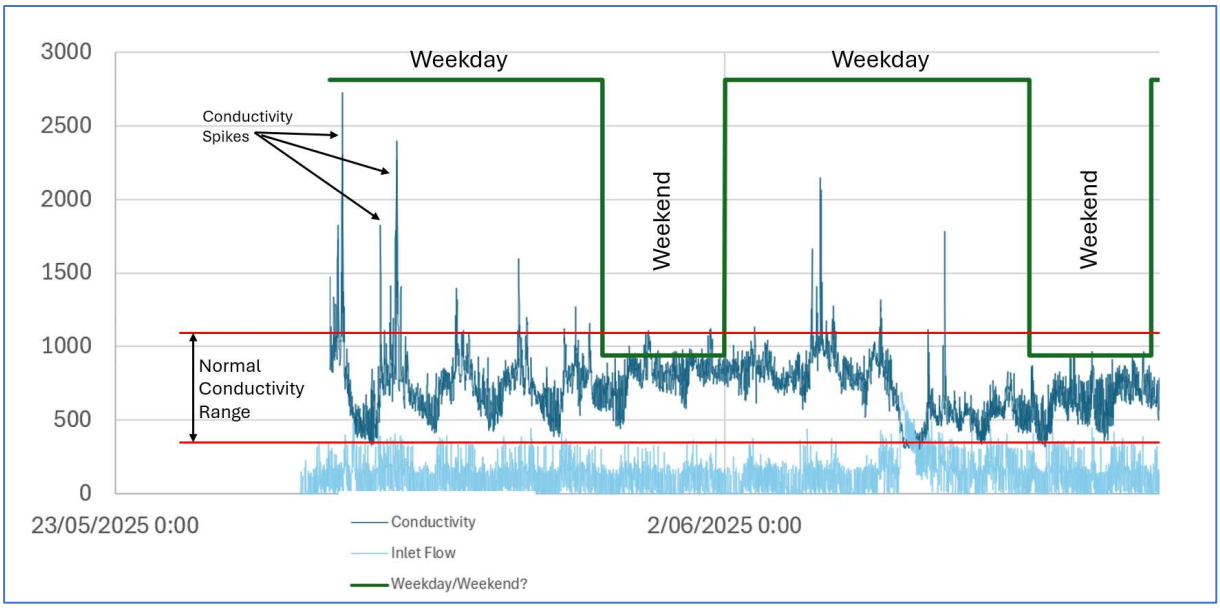
The panel endorses the ICM approach to better refine the understanding of interactions (and effects) between ERSs and the associated discharge environments both in terms of hydraulics and water quality.

It is recommended that SW consider targeted use of IoT level sensors at ERSs and the discharge waterways (operating in tandem) to confirm the model’s accuracy of hydraulic

interactions including backwater effects. Without sufficient monitoring data covering a range of weather and waterway conditions (including tidal impacts), it is very difficult to model these variable conditions with any certainty. Given the potential for waterway conditions to have a substantial impact on the hydraulics of ERSs, the panel recommend development of a specific plan to monitor conditions sufficiently to ensure the ICM models are fit for purpose.

The water quality sampling program proposed for the sewerage system should provide suitable data for DWF calibration of WQ parameters. Globally, the process of modelling water quality in sewerage systems has evolved – with a focus on monitoring key parameters which can act as surrogates and/or tracers for simulating other parameters which are part of an overall ERS effects assessment approach. Given that the "strength" of wastewater can vary substantially as a function of inputs sources (residential, commercial, industrial, others) and inflow/infiltration rates (including groundwater infiltration), monitoring parameters which can be measured in real time with continuous probes can provide a much greater insight as to how best to represent water quality in sewers. For example, ammonia, pH, temperature and conductivity are examples of direct and surrogate parameters which can be measured in real time using continuous probes. This approach does require active maintenance to ensure the probes operate as intended in these harsh environments, but this has been successfully implemented on many studies around the world.

Following is an example plot of real time conductivity, measured in the raw sewage influent to a treatment plant, to track down likely trade waste sources causing plant performance issues. This data shows clear "spiking" patterns which correlated directly with changes in the sewage strength associated with input sources. In this case this led to the identification of the problematic trade waste entities operating outside of their license agreements.



To complement the periodic and intensive sampling program the Panel recommends further consideration of installing continuous quality probes at key sites in the vicinity of proposed intensive sampling locations. The data from such probes will provide seasonal context to the

data collected during the intensive sampling periods as well as identification of periods anomalous data. This data will further enable model calibration to sewer water quality parameters including how they fluctuate in wet weather conditions when ESRs are likely triggered – enhancing the representation of overflow discharges beyond simplistic event mean concentrations which tend to normalise relative pollutant load contributions and effects.

2.13 Session 20: OACIS 3 – Widgets for Mike+

Summary

Mr Aman Kidanemariam provided an informative presentation on the works undertaken to adapt the legacy OACIS software, originally developed in 2000, to be able to:

- export modelling data in a format suitable for the Mike+ software.
- initiate simulations using the Mike1D hydraulic engine.
- extract results from Mike simulations and import into the Graph Manager and associated components.

The presentation provided a clear definition of the issues and challenges together with the logical workflows adopted to adapt the OACIS platform to interface with the Mike 1D simulation engine while only requiring relatively minor changes for the end users experience.

While it was acknowledged that these updates are an interim solution pending delivery of the future modelling platform the areas for potential future technical and operation risks are well defined.

Key themes are the need for process documentation to be thorough and regularly maintained over the transition period.

CRC Panel Discussion and Comments

Panel highly impressed with the clarity of the presentation, the definition and distinction of the workflows, the underlying software "widgets" developed and the ability to integrate the changes within the existing OACIS user interface to minimise adaption challenges for existing OACIS users.

The defined potential technical and operational risks associated with this transition software have been well defined together with considered mitigation strategies going forward.

The defined need to continually update documentation and development of a knowledge transfer strategy in relation to the OACIS software is commended.

While the example shown from the Narrabeen catchment, comparing modelled flows from the original MOUSE with the results from the Mike+ model for the same network appear

similar there may be need to expand the range of comparison tests. Comparison of the modelled outputs from large wet weather events in the vicinity of areas of complex hydraulics or known problem locations and ERSs should also be considered as part of the transition process to ensure that the Mike+ models demonstrate parallel performance.

2.14 Session 21: Stormwater 1D/2D Model Development

Summary

This presentation detailed the progress made in developing a model of the Sydney CBD catchment stormwater system.

A clear workflow was demonstrated that provided a logical sequence of activities.

The presenters discussed the work that has been completed to date (1D stormwater model build, 2D overland flow model build and rainfall-runoff model build) and identified future tasks includes coupling of 1D and 2D models, water quality modelling and LTS simulations.

The team highlighted the challenges with missing data in one of Sydney's oldest stormwater systems and reliance on the City of Sydney's asset database for information and discussed assumptions that were made to fill missing data.

The approach for developing the 2D model was discussed including the use of Mike Zero Mesh Generator to create high resolution elements.

CRC Panel Discussion and Comments

While still in its early stages the staged workflow presented demonstrated clearly how the outputs from this model will ultimately feed into the broader ICM work being undertaken

2.15 Session 22: Receiving Water Models

Summary

This presentation from Dr Pei Tillman demonstrated the receiving water modelling that has been undertaken by SW and some of the key outputs from these models and how they will feed into the broader ICM initiatives.

Modelling work to date has been swayed towards tidal and estuarine areas and the future focus is geared toward fresh water.

The proposed water quality sampling program, described in the Session 19 Integrated Catchment Modelling, will provide additional data to refine the calibration of the receiving water model and better quantify the impact of sewerage system overflows on the receiving waters.

CRC Panel Discussion and Comments

The incorporation of water quality parameters into the wastewater modelling aspect of the ICM program will provide useful inputs to better understand the contribution and impact of sewage overflows into the receiving water bodies. Based upon Panel members experience with sewerage system water quality modelling and sampling; the default use of event mean concentration for pollutants associated with overflows may be overly conservative at many locations.

The proposed monitoring program will enable the baseline models to be refined and coupled with the outputs from wastewater model overflows provide greater visibility of the actual contribution and impact of these overflows and in turn the benefits from source control programs.

2.16 Session 23: CRC Chairman's Wrap Up

Summary

The CRC concluded with a brief presentation from the Chairman summarising the key takeaways from the review. The Panel were overall very impressed with the advances that have been made over the past 3 years.

3 Findings with Regard to Objectives and General Discussion

The CRC Panel reports the following findings in response to the specific objectives outlined for the CRC:

- **PRP L7.1**

  Since the last CRC in 2022, the systems, methodologies and processes associated with the Licence Model update, verification and recalibration have been further refined from what was an already mature well understood system.

  The recent creation of the WWCMs, which has broken the larger systems into smaller receiving water based sub-systems for licensing purposes and rebuild of all models to a SCAMP level of detail is highly commended. This has enabled SW to maintain a single model that can be used across all areas of the business and provide a single source of "truth". This reduces the number of models to be maintained and avoids duplation of model build, model maintenance and model calibration efforts. The reestablishment of the current baseline (with the vast majority of ERSs now explicitly modelled) has been discussed with the EPA and we understand that no major concerns have been raised.

  With all WWCMs constructed to the same SCAMP level of detail, and particularly the explicit inclusion of the majority of ERSs in the model networks, has provided a firm foundation for the ICM modelling program.

  The ongoing system of Peer Reviews and Technical Management Reviews is well established and should ensure that the models are of a high quality and the results representative of the system performance. The Annual Reporting procedure is a well-developed process and seems to be implemented consistently.

  The Panel have noted that there has been a subtle change to the workflow over the past 3 years whereby models that have only had minor changes in the model update process have not been simulated with the previous year's rainfall for verification assessment.

  The succession planning issue identified at the previous has been largely addressed with the expansion of the team and broader resource base however an ongoing recruitment process will be required to ensure that resource levels are maintained. It is recommended that the team continue to build skills internally, particularly with regards to ensuring that there are sufficient people with the necessary skills to undertake peer reviews and technical reviews.

  The transition to a new modelling software platform is underway although it is recognised that this is a work in progress and is not expected to be fully implemented for another two years.

- **PRP Integrated Catchment Model**

  The Integrated Catchment Modelling program is a major undertaking, and the Panel are generally satisfied that the program has been well thought through as was demonstrated by the interconnecting workflows shown in a number of presentations.

  While the wastewater modelling aspects of the program should be achievable, the challenges encountered with the CBD stormwater modelling example will likely be encountered across much of the stormwater system. Engaging Consultants as additional resources to undertake much of this work will hopefully ensure that the proposed timelines will be achieved.

  The ongoing program of ERS inspections and additional gauging at ERS sites is encouraged. Those ERS locations that are predicted or known to discharge into submerged outlets due to the level in the stormwater system exceeding the ERS level are of primary importance for additional gauging.

  The addition of continuous monitoring to enhance the accuracy of ICM models, in our opinion, would add significant value to the use of these tools. This includes use of IoT level sensors and real time water quality probes as previously discussed.

  There are a few areas that the CRC Panel feels that SW need to address in the near term:

  - All models need to undergo annual verification following update. If a model has fallen out of verification tolerances, to not investigate the “why” is a lost opportunity for improvement. Given the WWCM models are now the single point of truth for Licensing, Planning and system analysis, it is important for downstream users to have an appreciation of the aspect of the models that need to be considered with a level of caution. Even if it is not possible to recalibrate every model that falls out of verification tolerances, providing an explanatory Tech Memo detailing the how and why of any discrepancy will inform and empower the downstream users to apply engineering judgement in those areas.
  - Calibration / verification issues were encountered in the Narrabeen and Shellharbour WWCMs when operational settings for pumping stations and storage facilities have on occasion been modified by the operators during wet weather events. These types of irregular operational changes will occur across the system and will impact the model performance during the annual verification simulations. The MOUSE RTC protocols are unable to adapt to these temporary changes in operational rules when running a longer time series simulation (i.e. one set of rules only for the whole simulation). In addition to compromising the results comparisons, between observed and modelled performance, it appears that a lot of modeller time is being expended to resolve or work around these types of issues. There is also the

possibility that other hydraulic issues are being masked by these workarounds. With the interim migration toward MIKE+ for all WWCMs, we note that there may be opportunity to leverage the “Time Series” sensor functionality, documented in the MIKE+ user guide, to reflect actual historical operation at these operators’ regulated facilities.

General Discussion Points and Considerations

As an overarching comment the Panel is extremely impressed with the remarkable transition that has occurred over the past 3.5 years within what is now the Engineering Modelling group.

The clear definition of the EM group’s roles and responsibilities, primarily Base Model construction and maintenance together with Growth model development, and the 6-year resourcing plan (2024-2030) to fulfill those roles has made clear the resourcing needs for the EM group. The distinction between what activities undertaken by the EM group are a Capital Expenditure by nature (e.g. the re-building of the tools and models primarily, model updates) and those that are Operational Expenditures by nature (e.g.recalibration, annual verification, STS reporting).

The Panel is impressed with the calibre and number of new recruits to the EM group. During the detailed Model Audits, and the CRC, the Panel were pleased to see firsthand their adeptness at working through the OACIS framework, understanding of the modelling processes and ability to readily access ad hoc information requests from the Audit panel. We also note that we were pleased with the openness shown by the team during Audits and the CRC and the overall positive collegiate and collaborative attitude displayed in both sessions.

Given the majority of the new team members have had limited previous exposure to the operation of a water and sewerage business, activities such as undertaking gauging site visits with the Hydrometric teams are strongly encouraged. The Panel would also recommend that site visits are arranged with operators when modelling large pumping stations and other complex facilities such as storage tanks.

In most water authorities, model development and concept level planning are generally undertaken within the same group. While the Panel concurs with the role distinctions of these groups within the current SW framework there are many potential benefits that could be derived from creating staff rotation programs between these groups. The less experienced Planners would gain a solid appreciation of what is involved the model development process and its nuances while the less experienced model developers would gain an appreciation of how the tools that they are developing are applied. In addition to expanding the knowledge of both groups it may also provide the opportunity for temporarily reallocating staff during crunch periods and potentially enable quick expansion of the resource pool to undertake peer and technical management reviews.

The transition to SCAMP level of detail in all WWCMs, and the resultant consistency of analysis across the network, has been a progressive improvement for the SW modelling program over a number of years that has now reached fruition. Breaking down the large North Head and Malabar system into a number of interdependent WWCM models has not been without challenges, particularly at the boundary interfaces. While this aspect of the program wasn't able to be fully reviewed over the time available during the Audit and the CRC, there may be opportunities to realign WWCM boundaries and/or relocate gauging to streamline this process going forward and additional permanent gauging sites need to be considered.

A quirk that came to light during the Audit of the WWCM calibration for Narrabeen was the use of LTS virtual rain gauges for calibration when higher resolution data was available from the temporary and permanent rain gauge network. We note that this was rectified in the Narrabeen presentation made at the CRC. While the application of the established virtual rain gauges needs to be maintained when undertaking the 10-year LTS simulations, during calibration the use of Theissen polygons developed with all permanent and temporary rain gauges is recommended.

During the Audit it was noted that the majority of the modelling associated guides and documents had not been reviewed for many years. With the major process changes, modelling platform etc that have occurred over recent years it is considered vital that these documents are reviewed, updated or replaced to ensure that these guides reflect the current best practice.

The work that was shown on the development of the "Widget" to enable OACIS to export model files in a MIKE+ format, launch model simulations and process and view results is to be commended as near-term fix until the future modelling platform is operational. While not thoroughly discussed during the CRC we recommend that a detailed comparison be undertaken between the MOUSE and MIKE+ model results, particularly at hydraulically complex areas of the model and at ERSs, to ensure that any differences are well understood with reference to LTS system performance.

4 Consolidated Recommendations

Based upon the range of matters and issues identified and discussed over the two days, the CRC Panel has consolidated the following recommendations for review by SW.

Rec No.	CRC Panel Comments/ Recommendations	Sydney Water's Accepted Improvement Initiatives/ Actions/ Commentary words	
Rec01	All WWCMs need to go through the annual verification process, regardless of how minor the updates and changes have been since the previous year.	Agreed in principle	Sydney Water will assess the resource and time requirements for verifying all WWCMS and determine whether these verifications should be conducted annually or biennially (once every two years).
Rec02	The stormwater component of the ICM program, given these will largely be completely new models, and knowing that stormwater asset data is often limited, will potentially be the critical path and recommend that progress be reviewed regularly. Provisional allowance for additional resourcing for this aspect of the program may be prudent.	Agreed	Sydney Water is building internal capabilities to automate GIS data processes, streamline stormwater catchment modelling procedures, and strengthen modelling resources to tackle complex tasks. In addition, implementing regular peer review processes will help ensure stormwater modelling stays on track and is delivered within the agreed timeframes.
Rec03	The issues identified with the inability of the MOUSE RTC functionality to replicate short term Operator interventions within a longer time series needs to be addressed in the future modelling platform. The MIKE+ platform, which all WWCMs are being migrated to in the near term as a temporary measure, may have the capability to replicate these types of irregular operations. Exploration of the capabilities of MIKE+ RTC is strongly recommended in the near term.	Agreed	The MIKE+ platform supports using external time series data (such as IICATS actual operations) to control MIKE+ RTC. Sydney Water will explore these capabilities and develop a procedure for incorporating them into model calibration and validation processes.
Rec04	Recommend that further consideration be given to the inclusion of continuous water quality monitoring to better understand sewage water quality and associated variability for ICM modelling.	Agreed in principle	Sydney Water plans to conduct a post-implementation review (PIR) of the ICM project once all deliverables are completed in late 2027. The review will assess the benefits achieved, capture lessons learned and identify opportunities for future improvements. The PIR will also include water quality monitoring within wastewater networks and evaluate water quality outputs from the ICM modelling.

Rec No.	CRC Panel Comments/ Recommendations	Sydney Water's Accepted Improvement Initiatives/ Actions/ Commentary words	
Rec05	SW to consider a rotation program for less experienced modellers between the EM group and Planning to increase skills and awareness in both groups and potentially increase the resource pool for TMR Reviewers.	Agreed	A working group has been established between Planning (the primary user of models) and Engineering Modelling to foster collaboration, improve processes, set priorities, and share knowledge to strengthen communication between the teams. This forum will also provide opportunities to explore job rotation and/or sharing programs, helping to build skill sets in modelling, planning, and model applications within Planning.
Rec06	For the larger systems such as North Head and Malabar, further refinement of the WWCM catchment boundaries and/or additional or relocation of permanent gauges needs to be considered in the near term to minimise inaccuracies and streamline calibration and verification modelling.	Agreed	The Engineering Modelling team will collaborate with Hydrometric Services to review the required boundary gauges and explore options such as adding or relocating gauges or merging catchment models to eliminate the need for boundary gauges.
Rec07	The majority of the modelling related guides and documents associated with the STS modelling need to be reviewed, updated and/or replaced with documentation that better reflects the current WWCM modelling processes in the near term.	Agreed	The Engineering Modelling team is currently developing new modelling procedures as part of the Integrated Catchment Modelling approach. In addition, Sydney Water will be transitioning to a new modelling platform, which will enable more advanced capabilities and improved efficiency. As part of these changes, the STS modelling-related documents will be reviewed and updated to align with future requirements and best practices.
Rec08	New or updated documentation to include distinction between calibration rain gauges and LTS virtual gauges.	Agreed	See responses to Rec 03 and Rec 07. The updated documentation will clearly distinguish between calibration and LTS run inputs, such as rain gauge data and actual operational data for RTC.
Rec09	Recommend that a rigorous and systematic procedure is developed and documented during model transitions to confirm that the MIKE+ model results compare well with the former MOUSE results, particularly at areas with complex hydraulics or at ERSs.	Agreed	The Engineering Modelling team, in collaboration with ICM project delivery partners, has developed detailed workflow instructions and a peer review checklist for converting models from the MOUSE platform to the MIKE+ platform, as well as for validation processes. Moving forward, the outputs from model conversion and validation will be documented in a comprehensive model build report for each system, ensuring consistency and supporting future enhancements.

Rec No.	CRC Panel Comments/ Recommendations	Sydney Water's Accepted Improvement Initiatives/ Actions/ Commentary words	
			These improvements will help streamline modelling practices, enhance quality assurance, and provide a solid foundation for future projects.