UNEXPECTED LEARNINGS FROM AN INFLOW AND INFILTRATION STUDY

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ABSTRACT

Infiltration and inflow (I&I) of groundwater and stormwater into sewer networks is an issue for water authorities across Australia. I&I causes increased flows into the sewer network which results in overloading of infrastructure and leads to environmental incidents. This paper presents the findings of a study investigating I&I of the AlburyCity sewer network. Although the aim of the study was to assess the magnitude and sources of I&I, as well as its impact on the overall performance of the sewer system, the outcomes included some unexpected findings. The findings of the study revealed highly variable levels of inflow and infiltration in the investigated area that were largely driven by catchment hydrology rather than storm intensity. Other utilities may benefit from assessing the extent to which catchment conditions affect I&I within their networks, as the influence of catchment conditions on I&I is unlikely to be unique to Albury.

1.0 INTRODUCTION

Albury City Council commissioned an Infiltration and Inflow study to help understand the impact of I&I on the Albury sewer network. The study was made up of 20 monitoring sites covering approximately half of the Albury sewer network.

The monitoring period was between October 2022 and February 2023 recording 8 storm events over this time period. A summary of the recorded storm events at each rain gauge is shown in Table 1.

Table 1: ***Summary of storm events recorded during the Albury I&I study***

Storm Event	Storm Return			Rainfall (mm)	Max. intensity (mm/hr)
	Kremur Street	Wodonga Place	Airport		
31/10 - 2/11/2022	2EY - 1EY	50% AEP - 20% AEP	4EY - 3EY	36 - 65	7 - 12
6/11/2022	2EY - 1EY	2EY - 1EY	6EY - 1EY	8 - 14	8 - 14
12/11 - 14/11/2022	10% AEP - 5% AEP	20% AEP - 10% AEP	2% AEP - 1% AEP	71 - 90	25 - 33
19/11 - 21/11/2022	4EY - 3EY	3EY - 2EY	2EY - 1EY	26 - 30	9 - 12
30/12 - 31/12/2022	>12EY	>12EY	2EY - 1EY	6 - 19	4 - 11
2/01/2023	12EY - 6EY	>12EY	>12EY	7 - 10	4 - 6
18/01/2023	2EY - 1EY	2EY - 1EY	20% AEP - 10% AEP	25 - 43	12 - 24
29/1 - 30/1/2023	200Y - 500Y	100Y - 200Y	200Y - 500Y	94 - 122	14 - 35

The preceding conditions for the study included higher than average rainfall in the 3 months prior to commencement and Murray River flows and flood levels also higher than average.

Part of the I&I assessment methodology included selecting dry days based on an antecedent precipitation index (API) less than 2.0. This methodology removes dry days where sewer flows are influenced by rainfall on previous days. Figure 1 below shows the calculated API for Albury before during and after the study period with the API threshold of 2.0 for a dry day indicated by the blue line across the bottom. This data demonstrates the catchment hydrology (soil moisture and groundwater levels) didn't dry out between the period of 3 months preceding the study to 4 weeks into the study.

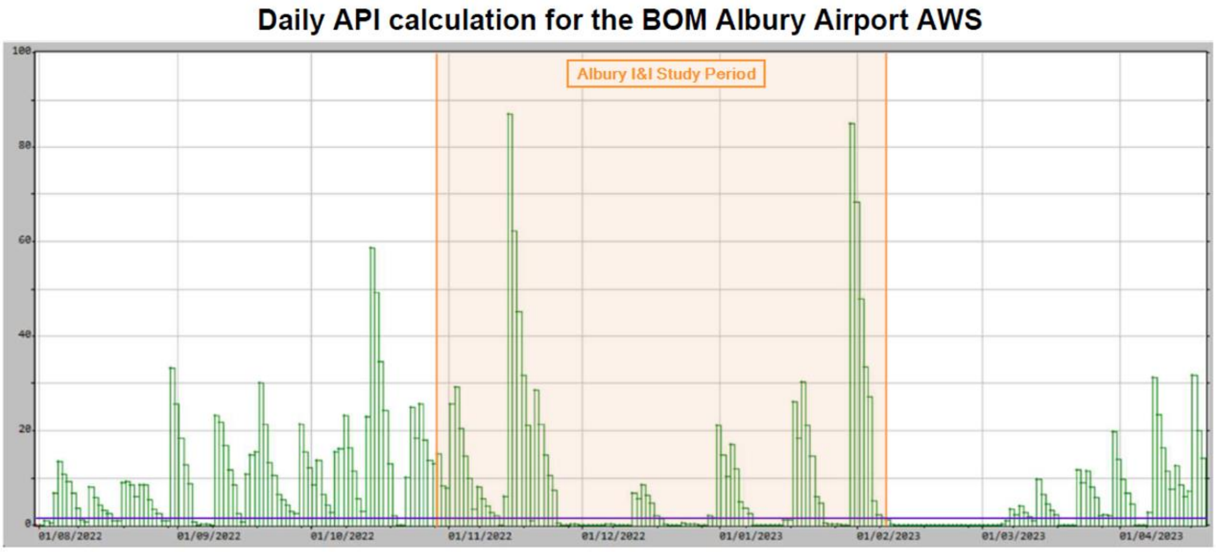

Figure 1: ***Daily API calculation for Albury – before, during and after I&I study***

In addition to the persistently high API preceding the study period, the water level in the Murray River at Albury was at its highest level in over 100 years with many low-lying areas along the river in flood. Figure 2 displays the river level peaking in November during the first weeks of the I&I study and being just shy of the highest level ever recorded (orange line).

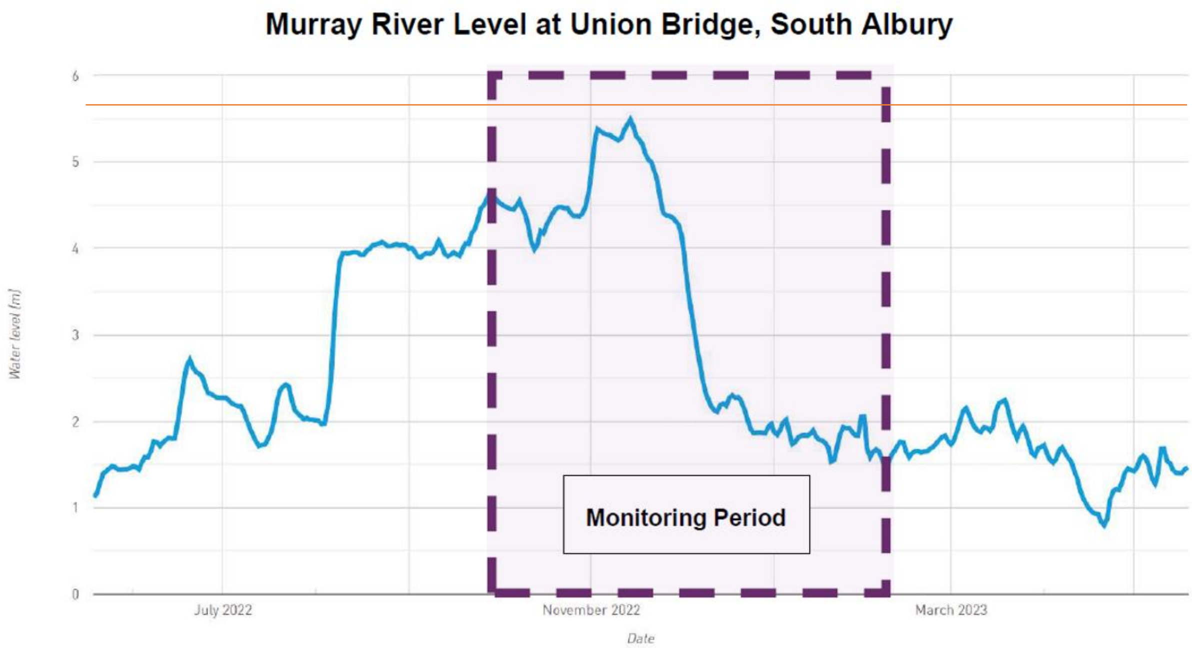

Figure 2: ***Murray River Level for Albury – before, during and after the I&I study***

Pooling water and soggy soils underfoot were observed across most of Albury during the installation of flow gauging equipment. These observations reinforce the high API calculations and high river level measurements at the time.

2.0 DISCUSSION

It was expected that saturated soils around Albury would have an impact on the amount of infiltration entering the Albury sewer, and that this may also have some impact on the amount of inflow entering during storm events. This assumption is widely accepted across the water industry, with many utilities experiencing higher base flows across the wetter months of the year compared to dry, due to the impact of the groundwater table. However, the extent to which the hydrological conditions in Albury impacted the sewer network were unexpected.

The I&I assessment used multiple metrics to gain a holistic understanding of the I&I characteristics of the Albury sewer network. For the purpose of this paper, the two metrics discussed are the percentage of RDII ingress (% RDII) and stormwater ingress (SWI) as these give a good indication of the location and magnitude of I&I issues across the network.

2.1 Percentage RDII

Rainfall Dependent Infiltration and Inflow (RDII) is a combination of Stormwater ingress (fast response) plus groundwater infiltration (slow response). The Albury I&I Study used the percentage I&I ingress (percentage of rainfall falling on an area that ends up in the sewer) to assess RDII within each sub-catchment. The Water Services Association of Australia (WSAA) Management of Wastewater System Infiltration and Inflow Good Practice Guideline 2013 recommends using a threshold value of 8% ingress before undertaking a cost-effective source detection and rehabilitation programme.

Table 2 below shows a summary of the %RDII of each sub-catchment with the 8 storms broken down into three categories,

1) Average %RDII of all 4 November events;
2) Average %RDII of the 3 events from December to mid-January;
3) %RDII for the >100 year return interval event at the end of January.

The data demonstrates that %RDII during the wettest hydrological conditions of the catchment are significantly higher than during periods of similar rainfall volume and intensity when the catchment had dried out. Further to this, the final storm event recorded at the end of January (> 100-year event) occurred during the driest period of the study. This event produced 122 mm of rain within 24 hours with a maximum intensity of 35 mm/hr yet produced some of the lowest %RDII of the entire study.

The final column of Table 2 also confirms this phenomenon where the largest recorded %RDII occurred most often during the more regular interval rain events (> 1 exceedance per year events) rather than the larger 1 in 2, 1 in 5 year and up to the 1 in 100 year events.

Table 2: ***Percentage RDII assessment summary***

Percentage RDII assessment results for Albury					
Sub-catchment	Average %RDII for November 2022	Average %RDII for January 2023	%RDII for >100-year event	Highest %RDII	Storm Return for highest %RDII
ALB_01	3.5	N/A	1.0	4.4	6EY - 4EY
ALB_02	2.5	1.0	0.9	4.4	4EY - 3EY
ALB_03	3.5	0.5	1.6	5.2	4EY - 3EY
ALB_04	3.6	0.6	1.3	4.8	4EY - 3EY
ALB_05	4.5	0.6	2.7	6.9	4EY - 3EY
ALB_06	6.1	0.1	2.1	**8.7**	50% AEP - 20% AEP
ALB_07	**11.0**	0.5	2.8	**22.9**	2EY – 1EY
ALB_08	4.3	0.6	0.6	**8.5**	2EY – 1EY
ALB_09	5.4	0.3	1.6	**11.4**	2EY – 1EY
ALB_10	**8.8**	0.4	2.2	**10.7**	50% AEP - 20% AEP
ALB_12	7.3	N/A	2.2	8.7	50% AEP - 20% AEP
ALB_13	**16.1**	2.0	5.2	**22.8**	2EY – 1EY
ALB_14	**9.7**	0.3	2.5	**12.6**	2EY – 1EY
ALB_15	**18.9**	4.6	1.9	**24.3**	2EY – 1EY
ALB_16	**23.2**	1.6	2.1	**37.7**	2EY – 1EY
ALB_17	2.9	0.7	1.0	3.9	50% AEP - 20% AEP
ALB_18	4.7	0.2	1.6	**8.5**	2EY – 1EY
ALB_19	**11.6**	0.5	3.2	**16.4**	2EY – 1EY
ALB_20	5.6	0.4	1.4	**8.4**	2EY – 1EY
ALB_21	3.1	0.6	0.9	4.9	2EY – 1EY

2.2 Stormwater Ingress

The assessment of stormwater ingress (SWI) used the SWI rate which is calculated by dividing the Peak Wet Weather Flow (PWWF) by the average Dry Weather Flow (ADWF). Many utilities may still use SWI ratios for planning and design, for example a wastewater trunk sewer may be designed to manage a PWWF to ADWF ratio of 5.0.

SWI rates are dependent on rainfall intensity more than rainfall total. Higher intensity rainfall events produce more overland flow and localised flooding as rain doesn't permeate the soil as readily, resulting in low manhole covers, uncapped I/Os, and low ORG's being exposed to stormwater inflow.

Table 3 below summarises the rate of SWI of each sub-catchment with storm events categorised as per the %RDII assessment methodology described above. Only 4 of the 20 sub-catchments recorded their highest SWI rate during the largest return interval storm (which also saw the highest rainfall intensity). Instead, most of the highest SWI rates for each sub-catchment occurred during events < 1 in 5-year interval.

Similar to %RDII, the key driver for SWI rates was the hydrological conditions within the catchment rather than the storm return interval.

Table 3: ***SWI assessment summary***

SWI assessment results for Albury

Sub-catchment	Average SWI for November 2022	Average SWI for January 2023	SWI for >100-year event	Highest SWI	Storm Return for highest SWI
ALB_01	9.1	5.5	8.3	17.4	2% AEP - 1% AEP
ALB_02	5.1	4.2	4.7	10.3	4EY - 3EY
ALB_03	9.1	9.8	10.6	12.0	2% AEP - 1% AEP
ALB_04	6.0	2.5	9.3	10.1	4EY - 3EY
ALB_05	15.3	13.9	27.8	27.8	200 - 500Y
ALB_06	7.9	4.2	10.3	10.7	20% AEP - 10% AEP
ALB_07	10.5	5.5	13.0	13.2	50% AEP - 20% AEP
ALB_08	5.3	2.9	6.2	7.1	2EY – 1EY
ALB_09	14.0	8.3	12.9	21.3	6EY – 4EY
ALB_10	11.8	8.1	16.3	16.3	100 – 200Y
ALB_12	5.6	7.0	7.0	9.4	20% AEP - 10% AEP
ALB_13	13.4	8.5	15.8	17.9	50% AEP - 20% AEP
ALB_14	7.5	4.5	8.9	13.5	50% AEP - 20% AEP
ALB_15	4.1	2.7	3.7	6.6	50% AEP - 20% AEP
ALB_16	5.9	5.3	8.3	8.3	100 – 200Y
ALB_17	6.9	4.7	8.6	8.6	100 – 200Y
ALB_18	10.6	5.4	12.4	13.9	50% AEP - 20% AEP
ALB_19	13.6	7.9	18.5	18.8	50% AEP - 20% AEP
ALB_20	13.8	7.6	12.1	22.1	10% AEP – 5% AEP
ALB_21	14.0	5.5	12.9	17.6	2EY – 1EY

2.3 The Anomaly

The %RDII for the entire Albury catchment area was calculated for five of the storm events, the results are provided in Table 4 below.

At first glance, the assessment of %RDII for the entire Albury catchment presents an anomaly in the form of the final storm event of the monitoring period. Over 115 mm of rainfall was recorded during this event, yet only 1.7% of that rainfall made it into the sewer. In comparison, on the 6th November 12 mm fell, with 10.6% of that rainfall making it into the sewer network. This anomaly was initially considered to be an error in the data collection or analysis. However, on closer inspection, and with the knowledge of the previous assessment of %RDII and SWI at the sub-catchment level, this data supports the I&I assessment for Albury i.e., high groundwater levels and a saturated catchment influence RDII much more than storm return interval.

Table 4: ***Total percentage RDII for entire Albury catchment area***

Total percentage RDII in Albury

Start Date	End Date	Combined WWTP Flow Volume (ML)	Dry Weather Volume (ML)	Volume Difference (ML)	Rain Total (mm)	Catchment Area (Ha)	%RDII
30/10/2022	6/11/2022	253.58	112	141.58	64.8	3422	6.4
6/11/2022	10/11/2022	114.85	70	44.85	12.4	3422	10.6
12/11/2022	19/11/2022	246.98	112	134.98	71.2	3422	5.5
19/11/2022	24/11/2022	130.10	84	46.10	28.6	3422	4.7
29/01/2023	2/02/2023	135.49	70	65.49	115.4	3422	**1.7**

2.4 Implications for other utilities

Catchment hydrology was found to be a much more significant contributor to I&I issues than storm return interval. This finding has a number of implications for other utilities.

Firstly, placing more importance on the level of nearby waterways and the local groundwater table may provide greater preparedness for operational teams when anticipating peak wet weather flows compared to relying on weather forecasts and observations of high intensity, high rainfall events.

Secondly, being aware of the difference in I&I magnitude depending on catchment hydrological conditions is important in getting a true reflection of the I&I within your sewer network. For example, if Albury City Council had commenced this I&I study 6 weeks later, the findings of the report would have concluded that Albury does not have any I&I problem. Therefore, a successful I&I assessment relies on either the I&I study capturing both hydrologically wet and dry catchment conditions or the utility understanding how their catchment hydrology impacts I&I.

3.0 CONCLUSION

Despite the understanding that high groundwater has an impact on I&I within the Albury sewer network, the exact magnitude of this impact that was uncovered through this study was unexpected. Storm return intervals are often quoted following storm events and incident debriefs however catchment hydrology was identified to be a far more significant contributor.

Being aware of the major drivers for I&I will allow Albury to be better prepared during future hydrologically wet periods.

This paper highlights the potential major impact of catchment hydrology as a driver of I&I within sewer networks. Other utilities may benefit from assessing the extent to which catchment conditions affect I&I within their networks, as the influence of catchment conditions on I&I is unlikely to be unique to Albury.

4.0 ACKNOWLEDGEMENTS

Thank you to Peter Stephens of Mott Macdonald Consulting for your very diligent work setting up, collecting and analysing of the Albury I&I study data. Peter prepared a detailed yet succinct, highly technical report with this technical paper only discussing one of many of the interesting findings of the report.

5.0 REFERENCES

WSAA 2013, Management of Wastewater System Infiltration and Inflow Good Practice Guideline – Volume

Mott Macdonald 2023, Albury Infiltration and Inflow Assessment