BLUE-GREEN ALGAE SOUP AND THE OPERATIONAL CHALLENGES OF A THREE-MONTH LONG BLOOM

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ABSTRACT

In early February 2016, Goulburn Valley Water received Blue-Green Algae data from Goulburn-Murray Water (G-MW) and the Murray & Sunraysia Regional Algal Coordinating Committees (MRACC) advising of elevated Blue-Green Algae bio-volumes upstream of GVW's Murray River offtakes. Analysis of this data triggered an additional urgent sample run on the 19th of February for Barmah and Cobram. Based on the results from these two samples the MRACC immediately issued a BGA Red Alert for these localities. This paper documents the operational challenges during the three month event and the steps taken by Goulburn Valley Water prior to and after the issuing of the Red Alert, including the preventative actions at Barmah and Cobram prior to the alert, the installation and commissioning of a trailer mounted bulk bag PAC dosing unit at Numurkah and temporary dosing systems setup at Picola and Nathalia.

1.0 INTRODUCTION

GVW has previously experienced significant blooms of Blue-Green Algae (BGA) along the Murray River. These have typically been related to *Dolichospermum (Anabaena)* and *Microcystis*. The dominant BGA species during this event was *Chrysosporum c.f. ovalisporum*, which has not been detected by GVW at alert levels before. Additionally GVW has not previously seen evidence of BGA in the Broken Creek and the presence of *Chrysosporum* was a first. Yarrawonga via the channel system is the source water for the storages at Numurkah, Katamatite & Picola and Nathalia, located on the Broken Creek. At the end of October 2015, GVW participated in the pre-season meeting with the BGA Regional Coordinator G-MW and other stakeholders. The BGA name changes and family groupings were also discussed; specifically that in the absence of diacritical features it becomes necessary to report BGA in groups (species resembling *Chrysosporum c.f. ovalisporum* could end up in the *Chrysosporum* or *Aphanizomenonaceae* family groups) and that the new *Aphanizomenonaceae* family group was considered toxic. Bio-volumes (mm^3/L) reported in this paper will be Total followed by combined Toxic & Potentially Toxic in brackets e.g. 11.68 (9.25)

2.0 DISCUSSION

2.1 Red Alert Declaration

G-MW and MRACC email through status reports to GVW on a regular basis and the results reviewed in-house. On the Fifth of February GVW received the MRACC algae spreadsheet. Review of this highlighted that *Dolichospermum circinale* had tipped over the Drinking Water trigger at Picnic Point, approximately 25km up-stream of GVWs offtake at Barmah. Carbon Dosing was initiated as a precautionary measure until sampling and analysis could be completed. The same day GVW received the laboratory reports forwarded from G-MW for the sample taken Monday the 1st at the Yarrawonga Outlet, bio-volume 0.25 (0.16). On Feb 11th GVW received the results for the Barmah offtake, 0.94 (0.45) the bio-volume of *Aphanizomenonaceae* in this sample was 0.18 mm^3/L. Carbon dosing continued at Barmah with weekly BGA sampling for external analysis for both Barmah and Cobram and normal in-house operational monitoring continuing at the other Northern District sites.

Given the result, the Co-ordinator of MRACC was contacted and the notification protocol confirmed. The advice being that while Victorian Authorities often advise the MRACC of results, it is a courtesy not an obligation. Thursday the 18th GVW received notification from G-MW that high levels of the BGA family *Aphanizomenonacae* had been identified at several Yarrawonga sites, outlet 4.22 (4.09). GVW immediately initiated carbon dosing at Cobram and put a hold on the refilling of all off-stream storages supplied from Yarrawonga until the risk evaluated. Friday the 19th GVW received further results for Barmah, 4.15 (3.25) (*Aphanizomenonacae* 2.93) and Cobram 4.08 (3.02) with the toxic bio-volume dominated by *Chrysosporum c.f. ovalisporum*. These results were forwarded to G-MW, MRACC & DHHS and an emergency sample run immediately undertaken with an additional sample run including toxins scheduled for the following Monday. The results for the emergency sample run for Barmah were received Monday the 22nd showing potentially toxic *Aphanizomenonaceae* dominating the sample 8.56 (7.53). This was immediately reported & highlighted to both G-MW and MRACC with direction sought regarding the declaration of a regional bloom.

This question raised confusion because of the differences between State jurisdictions and the format of laboratory reporting, as the *Aphanizomenonaceae family group* was being reported as 'potentially toxic'. To declare a red alert G-MW required two consecutive results greater than 4.0 mm^3/L but the protocol for NSW was to declare on a single result greater than 4.0 and resample. The differences were discussed and a photo of the river condition sent to MRACC who then proceeded to prepare a Red Alert. Tuesday the 23rd the results for Cobram were available 7.59 (6.87) and based on the results MRACC issued the Red Alert for Barmah & Cobram with G-MW following suit for Yarrawonga the following day.

While it had taken two and a half weeks to exceed the Recreational trigger, <u>the Drinking Water trigger was exceeded in a little over a week.</u>

<u>Table 1:</u> ***Bio-volume results that triggered the Red Alert****

Sample Date Feb - Mar	Barmah	Picnic Point	Cobram	Yarrawonga
1st				0.25 (0.18)
9th	0.94 (0.45)	1.47 (0.2)		
16th & 17th	4.15 (3.24)		4.08 (3.02)	4.22 (4.09)
19th	*8.56 (7.53)**		*7.59 (6.87)**	
22nd & 23rd	11.68 (9.25)	23.31 (23.02)	6.66 (5.30)	*7.29 (6.63)**
29th	10.8 (9.89)		5.49 (4.44)	7.9 (7.67)
1st, 2nd & 3rd	12.17 (11.31)	15.42 (14.94)	6.23 (5.45)	14.91 (14.64)

2.2 Preventive Actions

The bloom affected six of GVWs Water Treatment Plants (WTP) - Barmah, Cobram, Katamatite, Nathalia, Numurkah and Picola. Based on the up-stream results GVW had already commenced carbon dosing at Barmah & Cobram prior to the red alert declaration. Carbon dosing at Cobram commenced later than Barmah as the toxic bio-volume at the Yarrawonga outlet (~distance upstream 60 km) was less than one third of the drinking water trigger and Operators had yet to observe an increase in toxic species in raw water samples (microscopy). The off-stream storages at Katamatite, Numurkah & Picola were filled prior to the declaration and did not yet pose a risk and this left Nathalia. As all of GVWs other mobile PAC units were in use at other sites a temporary unit comprising a repurposed lime slurry tank with a submersible pump as a mixer and a basic solenoid pump was assembled for Nathalia, with Picola receiving a similar setup in turn.

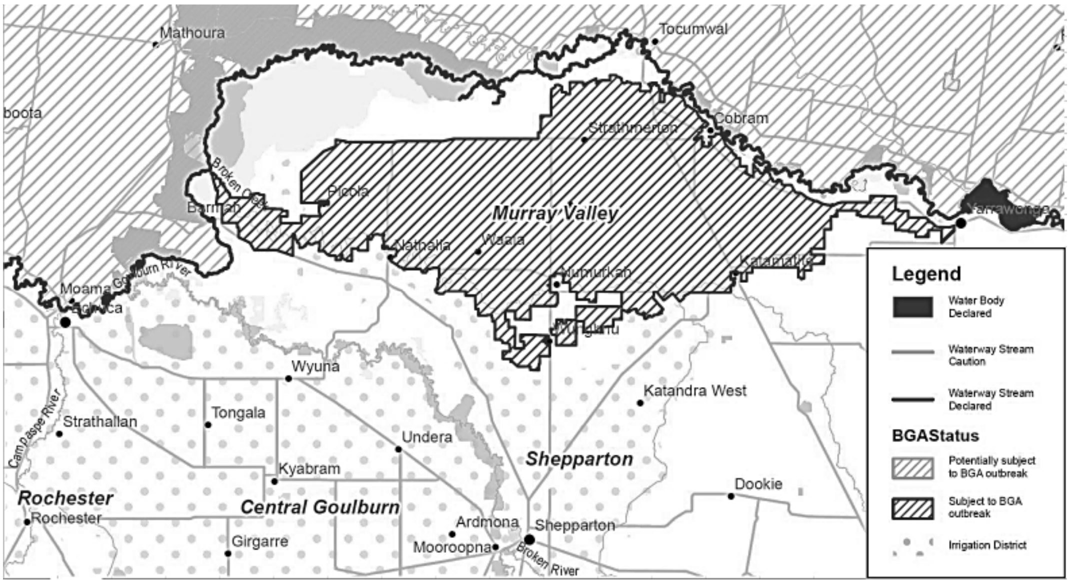

Figure 1: ***Excerpt from Murray River BGA alert public information map, State Government Victoria, 17 March 2016***

Katamatite was unique as pre-treatment with alum occurred in the raw water storage followed by Microfiltration and Chlorine disinfection. As no infrastructure existed for carbon contact at this site, the reliance was on the pre-treatment to prevent BGA growth in the reservoir and post treatment chlorine oxidation if toxins released. At maximum risk, the chlorine CT_{actual} was greater than four times the target of 60 mg.min/L for toxin oxidation. In the event that this was insufficient or Taste & Odour (T&O) compounds became a problem then tankering could easily supply the needs of the community. The pre-treatment was extremely effective and there were no issues with water quality during or after the bloom.

No Earthy or Musty odours were present but Toxin sampling and analysis for *Microcystin* – LR Toxicity Equivalents, *Cylindrospermopsin* (CYN) and *Deoxycylindrospermopsin* (Do-CYN) commenced for raw and treated waters as soon as the magnitude of the potentially toxic bio-volume was confirmed by Laboratory analysis. As part of the response all sites were assessed for CT and the free residual marginally increased where required, in order to exceed the target of 60. Additionally WTP wastewater recovery system operation was altered to prevent the reintroduction of algae cell concentrate to the raw water storages, system surveillance increased in line with risk and an inventory of carbon supply was undertaken. Logistics & continuity of supply was confirmed with the activated carbon supplier, Activated Carbon Technologies and a site meeting at Barmah arranged to highlight operational issues and brainstorm solutions.

2.3 Mobile Trailer Mounted Bulk Bag PAC Dosing

Raw water quality issues in the Broken Creek at Numurkah had been an intermittent problem prior to the construction of the new off-stream storage. Once the raw water supply switched to the new storage these issues disappeared and a stable three-year period of excellent raw water quality prompted a review of the justification to have permanent PAC dosing at the new DAFF plant. The decision was made to redirect the financial outlay from a permanent setup to a purpose built trailer mounted PAC dosing unit that while nominally based at Numurkah could be rapidly deployed at larger facilities. This proposal then needed to be fleshed out, as the volume of carbon required to meet the demand of the larger facilities would require intensive operator input if the design was undersized.

To meet this challenge an innovative design of a trailer mounted bulk bag system was developed by a team of representatives from GVW and the new WTP construction contractor Laurie Curran Water. This design would be truly mobile comprising a hydraulic demountable bag-lifting frame, hopper & feeder, dust extractor and a vacuum wetting cone & service water pump for dosing rather than a slurry tank. The frame included a monorail gantry and block & tackle so that no additional lifting equipment was required. This design enabled the mobile unit to be mounted on a single trailer removing the need for a shipping container or multiple trailers.

<u>Figure 2:</u> ***Unit packaged for transport and setup***

2.4 Operational Challenges

The first challenge occurred at Barmah. The operator had advised that maintaining a free chorine residual was increasingly difficult despite low filtered water NTU and True Colour. Filter to waste was installed and tankering commenced while the cause was evaluated. The cause appeared to be an overloaded clarifier as wasting had not increased in line with the increased loading, which had been an oversight. Compounding this issue sampling identified a manganese event in the midst of the bloom. The Manganese was closely monitored, as it was not advisable to pre-oxidise while the potentially toxic BGA was present. The tankering continued for three days which itself was an issue as Manganese deposits were resuspended and lead to customer complaints of dirty water.

The next challenge followed the decision to install tank level and no flow alarms as well as critical plant shutdown capability on all of the temporary dosing systems. The older solenoid pumps were changed to digital dosing pumps to enable alarming but this change meant a move away from the vigorous thump of the older pumps to a slow push of the digital pumps. This change caused blockages as they were no longer self-cleaning. The dosing at Nathalia was the most problematic with lime scale breaking away from the inside walls of the old slurry tank. Initially this was overcome by a thorough pressure wash of the tank followed by a change to a finer PAC but in the end a larger capacity tank was installed to enable greater slurry dilution and a mono pump was installed to deal with the older bags of carbon that contained more grit. Similar issues experienced at Barmah required a change from Acticarb WS 5-20 to PS1300F in 20 litre slurry pails followed by a reduction in solution strength from 2.5 to 0.5 % prior to dosing.

The setup of alarming at Picola was difficult due to the low flows and the small amount of carbon required. However, these works were never fully realised as operators undertaking the IT works observed a thick scum formation that started on the opposite side of the storage and over a matter of hours completely covered the raw water storage.

The decision was made at this point to cease operating the facility and commence tankering as the risk had greatly exceeded the capacity of the package plant to deal with the water quality. This was confirmed as the correct decision by algae bio-volumes that increased from 27.9 (27.5) to 75.6 (73.1). The storage at this point could only be described as *septic*.

These temporary dosing system problems were not alone. Because the mobile unit was rushed into service at Numurkah there had been no opportunity to test it and overcome any commissioning issues. The most significant issue was the failure of the feed screw as the original was inferior and did not have a central shaft and therefore no support. Other operational issues included optimising the operation of the wetting cone and the connection of the bulk bag to the hopper (requiring two-man operation). The collapse of the bloom was not the end of the operational issues. Prior to collapse Numurkah peaked at a bio-volume of 42.4 and Picola at 75.6. When these sites crashed there was a significant release of nitrogen and ammonia into the water leading to T&O complaints at Numurkah and on-going operational issues at Picola that at the time of writing have yet to be resolved.

2.5 Cell Counts & Toxicity

Initially total cells counts were requested of the Laboratory but TAT on multiple samples soon became problematic. In order to speed this up the requests were changed to BGA only (for raw water) and where possible non-toxic species were grouped as long as this did not adversely influence the calculation of bio-volumes. A column to identify potential and toxic species, as well as a bio-volume breakdown was added so that at a glance any employee with a basic knowledge of BGA triggers could make an objective evaluation of risk. The additional benefit of this was a reduction in double handling of data.

CYANOPHYCEAE						
Chroococcales small (iauv <20)		188	0	9219	5	0.04610
Chrysosporum c.f. ovalisporum (Aphanizomenon c.f. ovalisporum)	T	1874	0	91899	52	4.77874
Microcystis	P	0	428	840	74	0.06213
Planktolyngbya (short filaments)		14	0	687	30	0.02060
Planktolyngbya (long filaments)		9	0	441	120	0.05296
Pseudanabaena		6	0	294	12.5	0.00368
				Total Count		**Total Bio Vol.**
TOTAL BGA				103380		4.96420
TOTAL TOXIC BGA				91899		4.77874
TOTAL POTENTIALLY TOXIC BGA				840		0.06213

Figure 3: ***Blue-Green Algae report for Barmah 17/5/2016, modified to identify potential & known toxic species***

At Barmah cell removal was excellent but there was minor carry over that could not be predicted by turbidity as experienced following a minor increase in filtered water turbidity from 0.15 to 0.18 NTU. Algae removal mechanisms varies from species to species, requiring charge neutralisation and/or enmeshment in floc, so on-site testing with a portable Streaming Current device was used to determine the minimum concentration to achieve zero point of charge and the starting point for Jar tests. Selection of best jar was based on visual floc formation, settled NTU and Apparent Colour (filtered #1 Whatman) equalling a dose rate of 110 mg/L. Alternative coagulants, ACH and polyDADMAC blends were trialled but Alum was the chemical of choice for this site.

GVW undertook toxicity sampling for Microcystin, Cylindrospermopsin & Saxitoxin throughout the bloom on raw water, treated water and concentrated scum samples and for 100% of these samples the laboratory reported zero toxins greater than the LOR. The results raise the questions of; 1) sampling & analysis error, 2) toxin gene not switched on, or 3) the dominant species *Chrysosporum c.f. ovalisporum* is non-toxic. In a report on the toxigenicity of the bloom, innovative work undertaken by Associate Professor Aaron Jex at the University of Melbourne and the Walter and Eliza Hall Institute used a DNA-based diagnostic tool able to detect and quantify genes essential for the production of toxins. This work confirmed the presence of the toxin producing genes for the three toxin groups, demonstrating the potential for the production of toxins at the time and locations tested. This testing assessed the entire bacterial sample and not individually isolated species and while not validating the toxigenicity of *Chrysosporum c.f. ovalisporum* it provides a significantly important tool for the risk assessment of future blooms. The question of whether the toxin genes were switched on may be explained by the spike in nitrogen and ammonia following bloom collapse if nitrogen is inversely proportional to the potential for toxin production by the relevant gene cluster.

3.0 CONCLUSION

BGA blooms can exceed the Drinking Water trigger within days of identification and close monitoring of up-stream conditions and early action placed GVW in position to effectively respond to the increasing bloom in a timely manner. Despite the challenges, GVWs response was effective in being able to provide safe drinking water at all times during the event. Learnings;

- Early escalation is necessary to enable sufficient resource allocation
- Simple 'agricultural' carbon dosing can be effective but requires the highest quality powdered carbon to reduce operational issues.
- Low turbidity is an inaccurate indicator of cell removal and should be validated.
- Clarifier wasting needs to increase in line with the increased loading
- Manganese events can occur concurrently with the growth phase of BGA.
- Tanker connection points and filter to waste infrastructure should be in place and tested.
- Aluminium Sulphate pre-treatment in raw water storages is very effective for the control of *Chrysosporum c.f. ovalisporum.*
- If left untreated blooms of *Chrysosporum c.f. ovalisporum* in off-stream storages are likely to result in the release of Nitrogen and Ammonia after collapse.

4.0 ACKNOWLEDGEMENTS

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5.0 REFERENCES

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