12 February 2022

OUR REF: Waterside-2021-22/Fishkill

Client:

Donna Carroll
Len Robinson Strata & Community Management Pty Ltd
PO Box KL 925
KINGS LANGLEY NSW 2147

Dear Donna

WATERSIDE ESTATE LAKES MONITORING –LATERAL 2.2 FISHKILL INVESTIGATION

Please find below the results and discussion report on the Fishkill on Lateral 2.2, which occurred in the first week of **February 2022.**

1.1 BACKGROUND

The Waterside Green Estate is a residential zone incorporating several lakes and laterals. These water bodies are intended to: (a) add to the aesthetics of the area; (b) provide treatment and storage of stormwater; and (c) providing a refuge for native flora and fauna. Currently, the water bodies are being managed for aesthetic and public health purposes only. Recreational use is not advised, due to the potential for water quality issues arising from urban stormwater runoff.

Water enters the system via two main surface water inflow points, primarily from the south catchment through the Andrews Road inflow, and secondarily (usually only directly after rainfall events) from the east catchment via the Laycock Street inflow. Water exits the system via the Nepean Street outflow to the north and flows downstream through a small wetland into the Penrith Lakes North Pond. Waterside consists of five lakes and five associated laterals, which branch off to the west of each lake. A road bridge separates Lakes 1 and 2. A weir separates each of the other lakes.

Several water management systems have been installed at Waterside, including pumps, Underwater mixers and circulators, water fountains, water level control structures and gross pollutant traps (GPTs). These structures allow some control of the movement and quality of the water in the system.

- A sudden and unexpected Fishkill occurred in the first week of February 2022 in Lateral 2.2. No fishkill was noted in the other Lakes and Laterals. The fountain in Lateral 2.2 was not working for a few days prior to the event. This would haves exacerbated low DO conditions. The fountain was subsequently restored to operate at 8 am on 2nd February 2022 .
- To maintain water levels in Lateral 2.2, water from the bottom of Lake 3 (connected to Lateral 2.2) has been pumped in recent days (Geoff Hunter, *pers. comm*.). This was in a response to some residents complaining about the drop in water levels in the Lateral 2.2 of by about 200-300 mm in recent hot weather conditions.
- Despite fairly heavy rainfall over several months, Lateral 2.2 does not capture large volumes of rainwater because its immediate catchment is small.
- Lateral 2.2 has a maximum depth of about 2.5 m, a surface area of 12,800 m^2 (1.28 hectares) and a volume of 19,400 m^3 (Geoff Hunter, *pers. comm*.).
- Two floating aquatic species (*Azolla*, and possibly duckweed - *Lemna*) thrive in the Lateral 2.2 (**Figures 1-2**). Their undesirable visual effects have led to resident complaints in the past. These are periodically removed by harvesting and occasionally treated with an aquatic herbicide (Diquat – Reward®). The last spraying occurred on the 28-29th of January.

- At least some residents had complained about riparian plants (such as cumbungi – *Typha,* and other macrophytes) dying on the banks of Lateral 2.2, due to lower water levels, and the smell from decaying plant debris being obnoxious.

This report summarises and interprets the water quality monitoring data collected from Lateral 2.2 conducted on **8th February 2022**.

Figure 1 Lateral 2.2 – a photo showing the fountain in operation. The water surface is covered with azolla growth

Figure 2 Lateral 2.2 – another view showing the water surface covered with azolla growth

1.2 SCOPE AND OBJECTIVES

The objectives of the sampling program were to:

- (a) Conduct a visual assessment of Lateral 2.2 (**Figure 3**) and check on any obnoxious smells.
- (b) Establish the nutrients water quality in the Lateral 2.2, which is not routinely monitored.
- (c) Establish the dissolved oxygen levels in the water and other parameters with *in situ* water quality measurements; and
- (d) Check for the presence of any significant pesticides in the water as contaminants that might have affected the fish.
- (e) Report on the findings of the monitoring with discussion and make any useful recommendations.

Figure 3. Sampling Sites at Waterside Estate – the Red Circle shows the location of Lateral 2.2

2 METHODOLOGY

2.1 Visual Assessment

- The visual assessments on **8th February** afternoon (around 2:15 pm) indicated fairly turbid water but not excessively turbid. The dead fish had been removed but two other fish were recovered for disposal. The Lateral's water levels were slightly below the usual full capacity.
- A visual oil scum had been earlier reported. But the samplers did not notice any floating oil scum. There was no obnoxious smell from any decaying plant matter.
- Warm and humid conditions had continued for several days and were the same at the time of sampling with temperature hovering around 30°°C with hardly any wind.

2.2 Water Sampling and *In situ* Measurements

Routine water sampling was conducted by collecting several samples and making one **composite**. Samples were taken from just below the water surface.

***In situ* Physico-Chemical Water Quality Indicators:**

- Temperature, Electrical Conductivity, pH, Dissolved Oxygen, Turbidity; measured at four locations of Lateral 2.2 from a boat using a multi-parameter water quality probe.

Aquatic Ecosystem Health Indicators:

- Total Suspended Solids (TSS)
- Nutrients: Ammonia, Oxides of Nitrogen (NOx); and Total Nitrogen (TN); Total Phosphorus (TP), Soluble Reactive Phosphorus (SRP) – from a composite water sample.

Pesticides

- Organo-chlorine (OC) and organo-phosphorus (OP) pesticides – ultra-trace levels.

All samples were analysed at NATA accredited ALS Laboratories at Smithfield.

3 RESULTS AND DISCUSSION

3.1 Aquatic Ecosystem Health Indicators

The effects of the recent wet-weather event on nutrient contamination are evident in the results. Andrews Road and Laycock Street inflows contributed heavily to nutrient contamination of the system.

Table 1 shows the results of Lateral 2. 2 compared with the data from January 2022 from upstream flows (Andrews Rd inflows and Lakes 1&2) and the lake connected to Lateral 2.2 (Lake 3).

- Ammonium N and NOx levels were very low in Lateral 2.2 while these parameters were high or extremely high in the upstream lakes and Andrews Road inflows in January 22.
- Total N levels were high in Lateral 2.2, above the guideline. But the upstream and connected lakes and the Andrews Road inflows had higher or comparable levels. These appear to be organic forms of N.
- SRP concentrations were very low in Lateral 2.2 but high in the connected lakes and the Andrews Road and Laycock inflows.
- Total P concentrations were high in Lateral 2.2 and all Lakes and extremely high in the Andrews Road inflows.
- The very high TN and TP concentrations explain why the floating aquatic species (Azolla, and possibly Lemna) thrive in the Lateral 2.2. These are periodically removed by harvesting.

Table 1 – Macro-nutrient concentrations, routine sampling (8/2/2022)*

Analyte	Lake 1 & 2 (Jan 22)	Lake 3 (Jan 22)	Lateral 2.2 (Feb 22)	Andrews Road (Jan 22)	ANZECC Guidelines
Ammonia as N	**0.07**	**0.05**	<0.01	**0.13**	0.01
Nitrite + Nitrate	**0.08**	**0.05**	<0.01	**0.06**	0.01
Total Kjeldahl Nitrogen	0.8	0.8	1.2	5	-
Total Nitrogen	**0.9**	**0.8**	**1.2**	**5.1**	0.35
Reactive Phosphorus (SRP)	**0.04**	**0.02**	<0.01	**0.11**	0.005
Total Phosphorus	**0.12**	**0.09**	0.17	**0.96**	0.01
TSS	-	-	14	-	20

*Cells shaded in red indicate values exceeding guideline; cells shaded purple highlight very high values indicating extremely poor water quality regarding the measured parameter.

3.1.1 Field determined water quality parameters (Table 2)

The full results are given in Appendix 1. The average results of the vertical water quality profiles are presented below in Table 2.

- pH levels met the freshwater lakes guideline in all waterbodies (Table 2).
- Conductivity remained elevated, well above the ANZECC Guideline at all the sites and was extremely high at the two inflows (Table 2).
- DO concentrations were low to very low in most areas except the shallow South-East corner.
- DO concentrations well below the ANZECC Guidelines in the entire water column cause stress for fish.

Table 2 Field determined physico-chemical measurements (average) (8/2/2022)

	pH	Temp (°C)	Conductivity (µS/cm)	Dissolved Oxygen (DO) % Sat	Dissolved Oxygen (DO) mg/L	Turbidity (NTU)
Lateral 2.2 North-East	7.0	22.3	**297.2**	**68.3**	5.8	7.5
Lateral 2.2 South-East	7.2	23.0	**267.5**	96.5	8.2	145.2
Lateral 2.2 Middle	6.7	22.0	**313.5**	**41.6**	3.5	9.5
Lateral 2.2 West	6.7	22.7	**293.6**	**48.6**	4.1	44.7
ANZECC Guidelines	**6.5 - 8.5**	**N/A**	**20 - 30**	**80% – 110%**	**-**	**>20**

3.2 Vertical Water Profiles and Dissolved Oxygen

Figures 4 – 7 indicate the vertical profiles of Lateral 2.2.

The surface water temperature on **8th February 2022 was about 25.0 ^{0}C** and the bottom temperatures were about 5 ^{0}C lower than the surface.

Dissolved oxygen levels decreased rapidly with depth to be very low at the bottom. Mixing was not evident and this may have caused the water body to be oxygen depleted for many days. Low DO levels cause stress to fish.

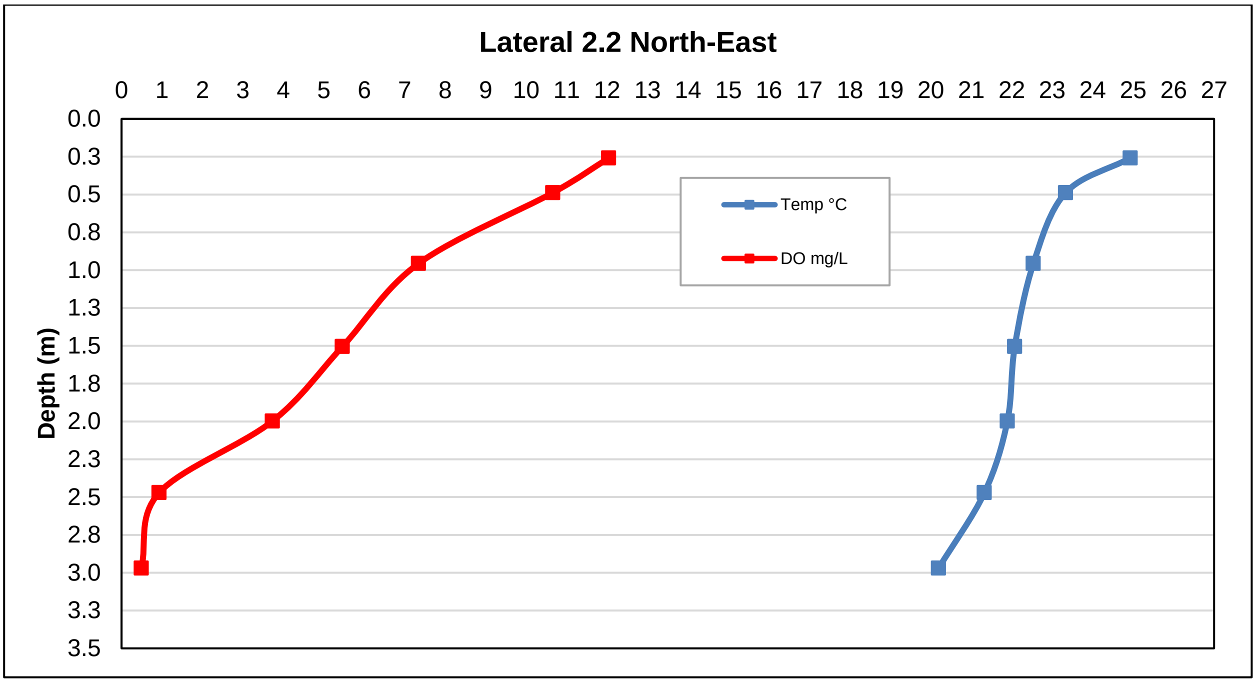


Figure 4 – Vertical profile for Lateral 2.2 North-East – 8th February 2022

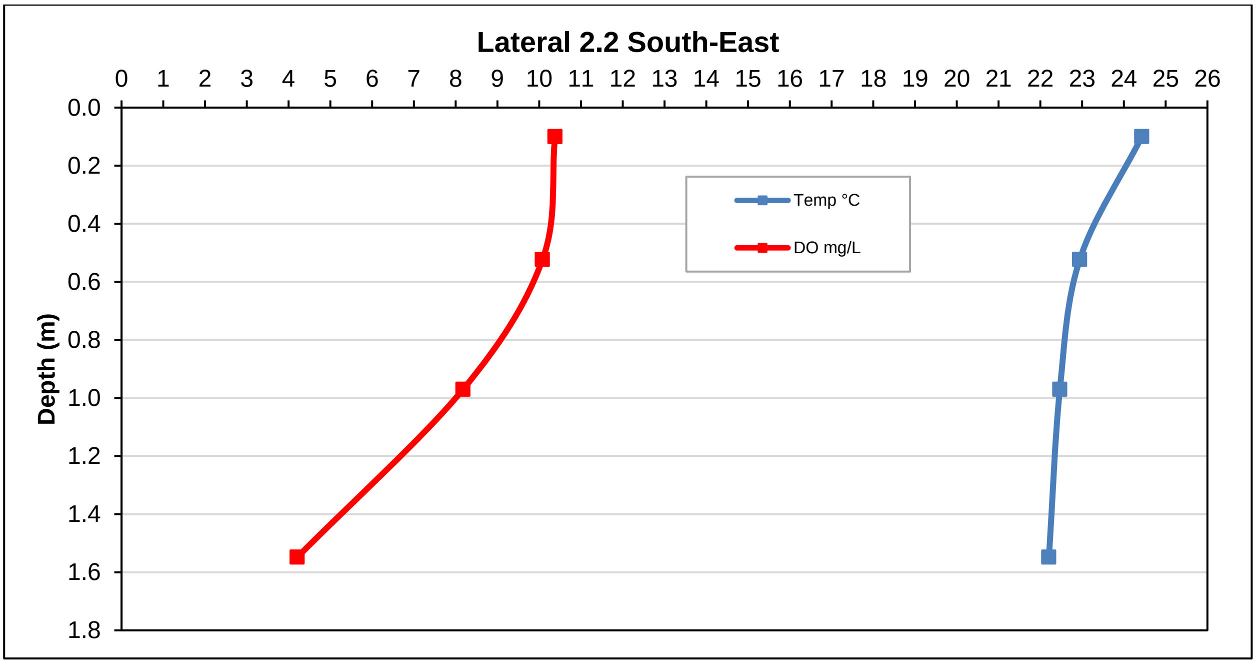


Figure 5 - Vertical profile for Lateral 2.2 South-East – 8th February 2022

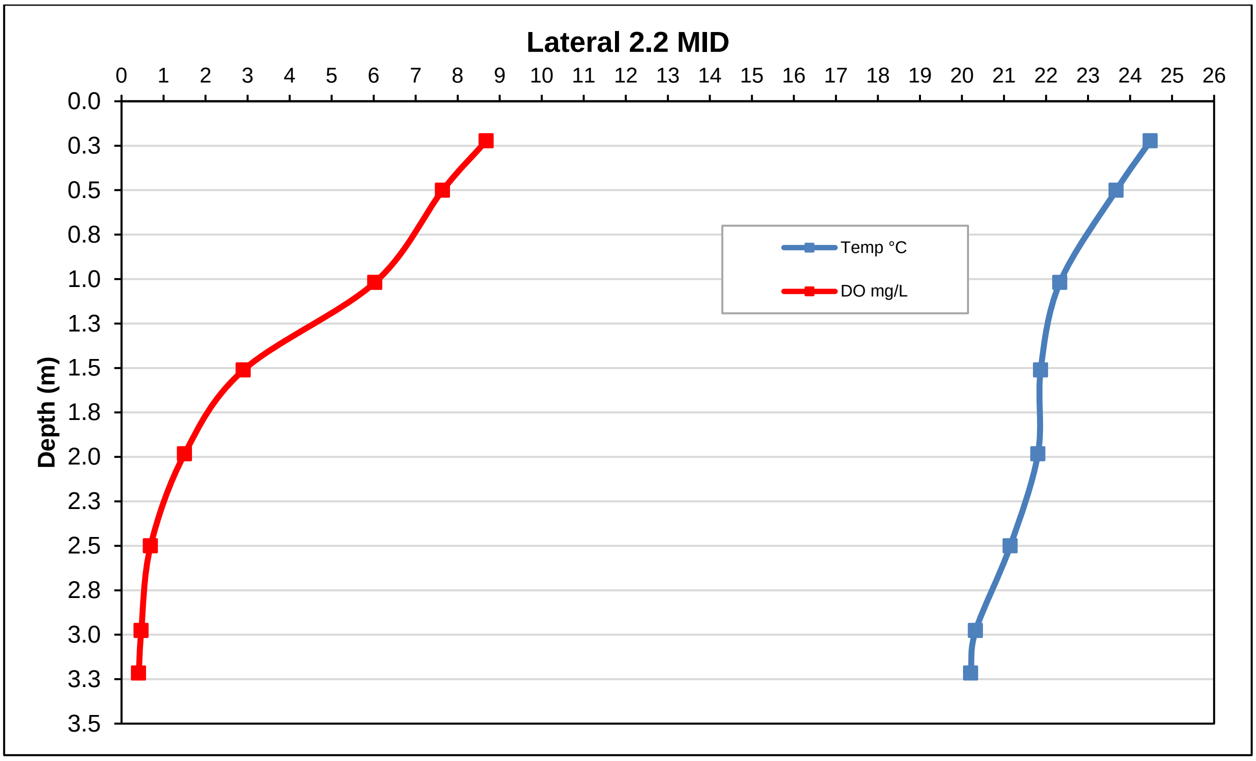


Figure 6 – Vertical profile for Lateral 2.2 Middle – 8th February 2022

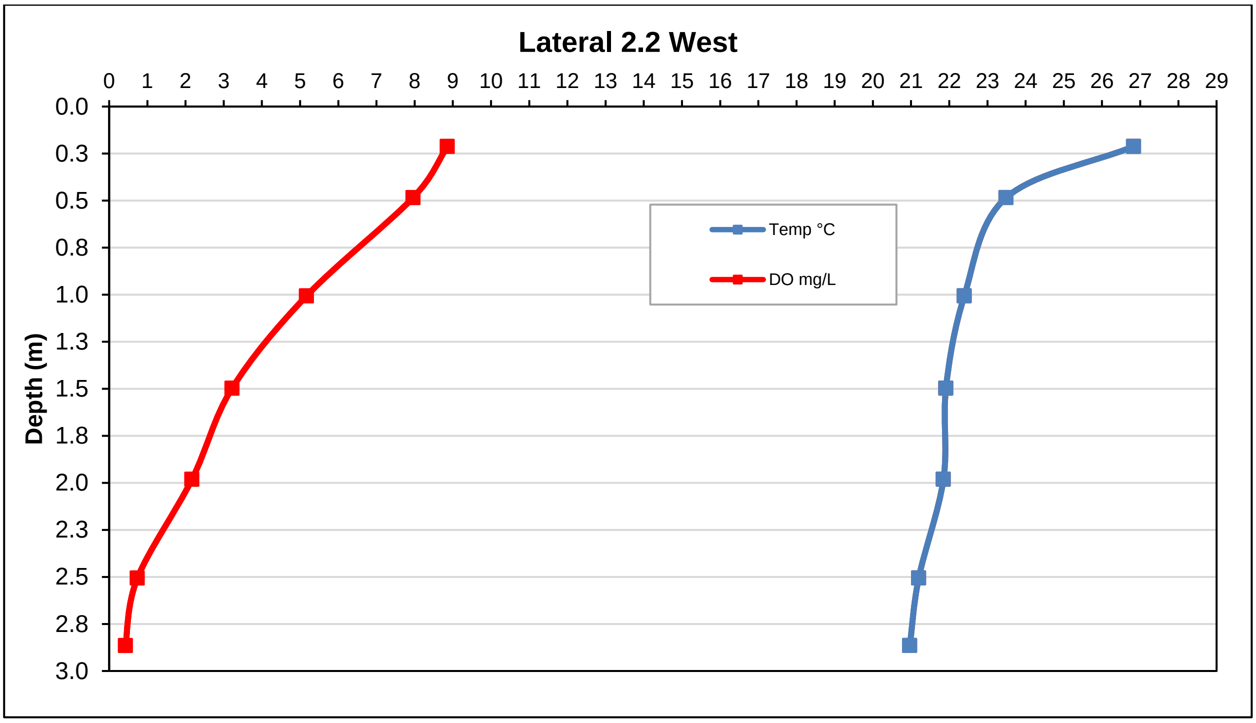


Figure 7 - Vertical profile for Lateral 2.2 West – 8th February 2022

3.3 Pesticide Scan

The results of the OC and OP pesticide Scan are given in Appendix 2. Ultra-trace detection was carried out by the NATA-accredited procedures using benchmark surrogates for analytical detections and procedure validation.

The results indicate NIL presence of the pesticides that can contaminate water from the most common household or environmental uses.

4 DISCUSSION OF SIGNIFICANT RESULTS

- The most likely cause of the Fishkill is oxygen depletion in the waterbody, caused by a number of likely factors. Stagnant water with surface temperature of around 28-30^{0}C or higher for extended period of time means dissolved oxygen would have been leaving the water body.
- Oxygen dissolution in water is affected by four key factors: (a) ambient temperature, (b) atmospheric pressure, (c) salinity level and (d) biological processes consuming oxygen. In general, in most freshwater bodies when the water is cool, it holds more DO.
- Cold water, around highest around 15^{0}C holds DO about 70-100% saturation. DO in deeper waters, especially in shallow lakes and ponds (non-flowing), is often limited by oxygen consumption by decaying processes and biological activities.
- The amount of dissolved oxygen needed varies from creature to creature. Bottom feeders, crabs, oysters and worms need minimal amounts of oxygen (1-6 mg/L; about 20-80% DO), while shallow water fish, including Carp, need higher levels (4-15 mg/L; 50% to above 100% DO).
- Usually, when fish are stressed due to lack of DO, **they will swim away or escape**. However, if there are no escape pathways, most will succumb even after short exposure to oxygen stress. The elderly fish are most likely more vulnerable. In the case of Lateral 2.2, fish appear to have been unable to swim away because of weirs and impediments (Geoff Hunter, *pers comm*. - to confirm).
- Sudden fishkills are often the result of "shock" due to lack of DO and are a common phenomenon in hot summers in shallow waterbodies (Note: Even in tidal rivers, such as the Parramatta River, fish get caught up in extremely low DO situations because of a combination of factors – a sudden rush of saline water with low DO; large amounts of organic matter due to wet weather ingress and hot, persistent temperatures].
- Rainfall in Dec 21 and January 22 was higher compared with previous months. These mostly flowed through the system but **did not fill the Lateral 2.2**. The water level in the Lateral decreased as a result, which prompted pumping water from the immediately connected Lakes 2 and Lake 3
- The pumped water from the bottoms of Lakes 2 and Lake 3 was already very low in DO (16% as indicated in the January 22 Waterside Water Quality Report). The water from the bottom of any lake is full of decaying organic matter and very fine silt, which can remain suspended in a water column.
- The influx of low oxygen water from Lakes 2 and Lake 3 with most likely, decaying organic debris would have created a further oxygen stress in Lateral 2.2. Decaying organic matter consumes oxygen extremely fast upon churning.
- **Nutrients** – No algal blooms were detected in the Lateral or in the Lakes. Therefore, nutrients likely did not contribute to the fishkill. However, high levels of plant nutrients, especially TN and TP, contribute to the aquatic plant growth. The floating aquatics do not get flushed out because of the design of Lateral 2.2. Therefore, their excessive growth needs to be managed with periodic interventions, like harvesting. **Regular and proactive harvesting** from a small boat will help in the future. Particularly, the removal from the edges can be done by wading into water and using nets or scoops.
- **Pesticides** – None were detected. Therefore, pesticides from domestic uses or environmental uses did not contribute to the fishkill.

- **Herbicides** – Staff of ***Bettersafe*** – a Licensed Aquatic Weed Control specialist and operator. sprayed the floating aquatics with Diquat, according to label recommendations. These volumes were small and calculated to cover the area that needed to be treated. The staff are accredited, licensed operators. No spill of Diquat occurred.
- Fish deaths occurred a few days after the herbicide applications. This is interpreted as a **coincidence rather than a cause**. No mass killing of plants occurred (which might have caused an oxygen depletion if the plants were submersed, died and decayed underwater).
- Diquat is safe to fish and also breaks down fast upon contact with colloidal matter in the water column. It is a '**CONTACT**' herbicide, which has to land on the plants for direct contact - to be effective. It has been used on Waterside Lakes and the adjacent Penrith Lakes for several years with no adverse effects on fish or any other fauna ever recorded.
- Typically, Diquat is undetectable in water within 24-48 hours because of rapid dissipation (dilution) and break down. On previous occasions, at Penrith lakes, Diquat has never been detected in water 24 h after treatment.

5 CONCLUSION

Depletion of dissolved oxygen in the water appear to have caused a 'shock' and stressed the fish, which resulted in the death of about 19-20 fish (up to the 8th Feb 22). Although these were European Carp (*Cyprinus carpio*), which are extremely hardy fish, the DO measurements, taken after the event, still show low DO conditions persisting in the Lateral.

Stagnant water, high temperature (persisting around 28-30^{o} ^{0}C at the surface and around 20^{o0}C at the bottom are conditions under which freshwater becomes oxygen depleted. It is a common phenomenon in hot summers. Some fish, most likely, elderly, are susceptible, unless they can swim away to a larger waterbody.

The pumping of water from the bottom of Lakes 2 and Lake 3, **low in DO or NIL oxygen** and decaying organic debris and colloidal matter would have exacerbated the oxygen depletion in Lateral 2.2.

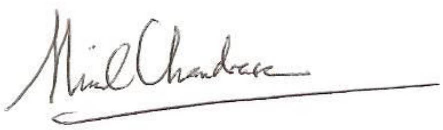
The fountain was not working for a few days prior to the event. This would have compounded the low DO conditions. The restoring of the fountain should ease the DO stress for fish.

Cooling conditions (anticipated) will also ease the situation.

6 CLOSURE

Please do not hesitate to contact the undersigned on Mobile: 0408 279 604 to discuss further.

Yours sincerely



Dr. Nimal Chandrasena

Principal Ecologist, For Bettersafe Environmental Services

(Trading Under: Bettersafe Pest & Weed Management Pty Ltd.)

APPENDIX 1 – Field physico-chemical measurements Sampling Event (8/2/2022)

Lateral 2.2 NE									Average
Depth	0.3	0.5	1.0	1.5	2.0	2.5	3.0		1.5
pH	8.1	7.6	7.1	6.9	6.8	6.4	6.5		7.0
Temp	24.9	23.3	22.5	22.1	21.9	21.3	20.2		22.3
EC	267.3	267.5	268.0	265.5	264.4	303.5	444.5		297.2
DO%	146.0	125.5	85.1	62.7	42.8	10.5	5.4		68.3
DO	12.0	10.7	7.3	5.5	3.7	0.9	0.5		5.8
Turb	4.9	8.0	7.0	3.7	3.5	9.0	16.2		7.5
Lateral 2.2 SE									
Sample Depth (m)	0.1	0.5	1.0	1.5					0.8
pH	7.6	7.4	7.2	6.7					7.2
Temp (°C)	24.4	22.9	22.5	22.2					23.0
Cond (µS/cm)	268.9	265.5	264.3	271.2					267.5
DO% (Sat)	124.7	117.8	94.7	48.6					96.5
DO (mg/l)	10.4	10.1	8.2	4.2					8.2
Turbidity (NTU)	7.1	7.0	12.1	554.9					145.2
Lateral 2.2 MID									
Sample Depth (m)	0.2	0.5	1.0	1.5	2.0	2.5	3.0	3.2	1.7
pH	7.2	7.0	6.9	6.7	6.6	6.4	6.4	6.4	6.7
Temp (°C)	24.5	23.7	22.3	21.9	21.8	21.1	20.3	20.2	22.0
Cond (µS/cm)	268.5	266.7	266.4	264.6	265.3	333.6	411.7	430.8	313.5
DO% (Sat)	104.4	90.6	69.6	33.3	17.2	7.8	5.2	4.5	41.6
DO (mg/l)	8.7	7.6	6.0	2.9	1.5	0.7	0.5	0.4	3.5
Turbidity (NTU)	5.8	5.5	5.2	3.5	6.0	8.9	14.0	27.0	9.5
Lateral 2.2 West									
Depth	0.2	0.5	1.0	1.5	2.0	2.5	2.9		1.5
pH	7.25	7.03	6.84	6.71	6.65	6.4	6.4		6.7
Temp °C	26.8	23.5	22.4	21.9	21.8	21.2	21.0		22.7
SpCond µS/cm	270.2	270.9	268.2	267.0	266.5	329.3	383.1		293.6
ODO % sat	111.2	94	59.8	36.9	24.8	8.3	4.9		48.6
ODO mg/L	8.86	7.96	5.17	3.22	2.17	0.7	0.4		4.1
Turbidity NTU	5.32	7.94	6.12	4.73	4.64	9.1	275.0		44.7

APPENDIX 2 - Results of the Organo-Chlorine (OC) and Organo-phosphorus (OP) Pesticide Ultra-Trace Scan

EP131A: Organochlorine Pesticides			
OC Pesticide	**Unit**	**Detection Limit**	**Detected Level**
Aldrin	µg/L	0.01	<0.010
alpha-BHC	µg/L	0.01	<0.010
beta-BHC	µg/L	0.01	<0.010
delta-BHC	µg/L	0.01	<0.010
4.4`-DDD	µg/L	0.01	<0.010
4.4`-DDE	µg/L	0.01	<0.010
4.4`-DDT	µg/L	0.01	<0.010
Dieldrin	µg/L	0.01	<0.010
alpha-Endosulfan	µg/L	0.01	<0.010
beta-Endosulfan	µg/L	0.01	<0.010
Endosulfan sulfate	µg/L	0.01	<0.010
Endrin	µg/L	0.01	<0.010
Endosulfan (sum)	µg/L	0.01	<0.010
Endrin aldehyde	µg/L	0.01	<0.010
Endrin ketone	µg/L	0.01	<0.010
Heptachlor	µg/L	0.005	<0.005
Heptachlor epoxide	µg/L	0.01	<0.010
Hexachlorobenzene (HCB)	µg/L	0.01	<0.010
gamma-BHC	µg/L	0.01	<0.010
Methoxychlor	µg/L	0.01	<0.010
cis-Chlordane	µg/L	0.01	<0.010
trans-Chlordane	µg/L	0.01	<0.010
Oxychlordane	µg/L	0.01	<0.010
Sum of Aldrin + Dieldrin	µg/L	0.01	<0.010
Sum of DDD + DDE + DDT	µg/L	0.01	<0.010
EP131S: OC Pesticide Surrogate			
Dibromo-DDE 21655-73-2	%	0.1	70
NO OC PESTICIDES DETECTED IN THE SAMPLE			

EP234A: OP Pesticides			
OP Pesticide	**Unit**	**Detection Limit**	**Detected Level**
Azinphos-methyl	µg/L	0.02	<0.02
Azinphos-ethyl	µg/L	0.02	<0.02
Bromophos-ethyl	µg/L	0.1	<0.10
Carbofenothion	µg/L	0.02	<0.02
Chlorfenvinphos	µg/L	0.02	<0.02
Chlorpyrifos	µg/L	0.02	<0.02
Chlorpyrifos-methyl	µg/L	0.2	<0.2

EP234A: OP Pesticides			
OP Pesticide	**Unit**	**Detection Limit**	**Detected Level**
Coumaphos	µg/L	0.01	<0.01
Demeton-O	µg/L	0.02	<0.02
Demeton-O & Demeton-S	µg/L	0.02	<0.02
Demeton-S	µg/L	0.02	<0.02
Demeton-S-methyl	µg/L	0.02	<0.02
Diazinon	µg/L	0.01	<0.01
Dichlorvos	µg/L	0.2	<0.20
Dimethoate	µg/L	0.02	<0.02
Disulfoton	µg/L	0.05	<0.05
EPN	µg/L	0.05	<0.05
Ethion	µg/L	0.02	<0.02
Ethoprophos	µg/L	0.01	<0.01
Fenamiphos	µg/L	0.01	<0.01
Fenchlorphos (Ronnel)	µg/L	10	<10
Fenitrothion	µg/L	2	<2
Fensulfothion	µg/L	0.01	<0.01
Fenthion	µg/L	0.05	<0.05
Malathion	µg/L	0.02	<0.02
Mevinphos	µg/L	0.02	<0.02
Monocrotophos	µg/L	0.02	<0.02
Omethoate	µg/L	0.01	<0.01
Parathion	µg/L	0.2	<0.2
Parathion-methyl	µg/L	0.5	<0.5
Phorate	µg/L	0.1	<0.1
Pirimiphos-ethyl	µg/L	0.01	<0.01
Pirimiphos-methyl	µg/L	0.01	<0.01
Profenofos	µg/L	0.01	<0.01
Prothiofos	µg/L	0.1	<0.1
Sulfotep	µg/L	0.005	<0.005
Sulprofos	µg/L	0.05	<0.05
Temephos	µg/L	0.02	<0.02
Terbufos	µg/L	0.01	<0.01
Tetrachlorvinphos	µg/L	0.01	<0.01
Triazophos	µg/L	0.005	<0.005
Trichlorfon	µg/L	0.02	<0.02
Trichloronate	µg/L	0.5	<0.5
NO OP PESTICIDES DETECTED IN THE SAMPLE			