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Environmental Impact Statement – Appendix Q: Water Quality Statistical Analysis

Warragamba Dam Raising

Reference No. 30012078
Prepared for WaterNSW
10 September 2021

SMEC INTERNAL REF. 30012078

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1 Introduction

1.1 Background

WaterNSW, a New South Wales (NSW) state owned corporation, is seeking planning approval for the Warragamba Dam Raising Project (the Project). The approval is sought under Division 5.2 (section 5.12) (State Significant Infrastructure) of the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act).

To support the project approval application, an environmental impact statement (EIS) is being prepared. This report is part of the EIS and provides detailed analysis and data to support the assessment of the Project's impact on water quality which is contained in Chapter 27 of the EIS. The Secretary's Environmental Assessment Requirements (SEARs) that the water quality assessment addresses are also discussed in Chapter 27.

1.2 Scope

This water quality report contains supporting information and analysis for the more detailed assessment of water quality impacts of the Project contained in Chapter 27 of EIS. It is not intended that this report completely address the relevant SEARs relating to water quality – rather Chapter 27 contains sufficient information to address all the relevant SEARs. Specifically, this report contains:

- water quality data from various sites in Lake Burragorang from before (pre event) and after (post event) rainfall events that were used as surrogates for assessing the likely water quality in the flood mitigation zone when the Project is operational
- statistical analysis of the data to determine whether the pre and post event data was representative of typical water quality conditions in Lake Burragorang.

The context and methodology for the use of surrogate events to estimate flood mitigation zone water quality and assess potential downstream water quality impacts during the discharge of the flood mitigation is described in detail in Chapter 27 and summarised in the following sections to provide context.

2 Methodology

2.1 Methodology

2.1.1 Introduction

Water quality modelling for the downstream Hawkesbury-Nepean River was available including consideration of environmental flow releases. A review of upstream data found that there were suitable inflow events that could be representative of the flood mitigation zone water quality. To assess potential downstream water quality impacts from the discharge of the flood mitigation zone, the following process was undertaken:

- identify surrogate inflow events that would be similar to the capture of the flood inflows by the flood mitigation zone
- collate and analyse appropriate water quality data from the specific events to estimate water quality in the flood mitigation zone
- compare predicted water quality of the flood mitigation zone with downstream water quality from Hawkesbury-Nepean modelling to identify any impacts in relation to NSW Water Quality Objectives (WQO) (Department of Environment, Climate Change and Water (DECCW) 2006)
- identify any recommended mitigation measures.

The first three stages of the above process are described in the following sections. Mitigation measures are addressed in Chapter 27, Section 27.6.

2.1.2 Selection of surrogate events

Historical daily storage data from Warragamba Dam (sourced from WaterNSW) was examined to identify surrogate events that would mimic the filling of the flood mitigation zone before discharge. In reviewing historical water quality and inflow data, there were very few events which met the criteria for a suitable surrogate event. The August 1998 and March 2012 events were found to be the best representative surrogates.

2.1.3 Surrogate event water quality

Monitoring location DWA2 is located about 500 metres upstream of the dam wall and is representative of the water quality flowing over the spillway. Although sampling was undertaken at multiple depths within the water column, the mean of water quality measurements taken from 0 to 18 metres was selected as a representative baseline value. This is because 0 to 18 metres would be representative of the water quality likely to be discharged from the flood mitigation zone.

The post event water quality data was defined as the 14 days following the flood event as this is a representative period to empty the proposed flood mitigation zone. For the 1998 winter event, post-event data was collected from 24 August to 7 September 1998. For the 2012 summer event, post-event data was sampled from 14-27 March 2012. Data for all events is presented in the following sections.

2.1.4 Water quality modelling

The Hawkesbury-Nepean Hydrodynamic Water Quality Model is supported by the EPA and can be used to (Sydney Water 2016):

- compare relative changes in water quality and flow under different management options
- determine whether it is likely that scenarios could achieve water quality targets
- assess the compounding impacts of changing land-use and growth
- assess the flow recurrence intervals and flow regimes in the catchment.

The Hawkesbury-Nepean Hydrodynamic Water Quality Model was used in this assessment to determine if:

- the changes in flow regime have an impact on the downstream receiving waters
- the changes in discharge water quality from the flood mitigation zone have an impact on the downstream receiving waters.

Existing modelled scenarios from the Hawkesbury-Nepean Hydrodynamic Water Quality Model were reviewed. The following six scenarios were found to be relevant to the Project and were used in the assessment:

- Scenario 5: Current discharges from Warragamba dam, 2011 land-use and 2011 discharges from wastewater treatment plant (WWTP)
- Scenario 7: Current discharges from Warragamba dam, 2030 land-use and 2030 discharges from WWTP
- Scenario 15: Current discharges from Warragamba Dam, 2050 land-use and 2050 discharges from WWTP
- Scenario 41: 90/10 Environmental flows from Warragamba Dam, 2011 land-use and 2011 discharges from WWTP
- Scenario 43: 90/10 Environmental flows from Warragamba Dam, 2030 land-use and 2030 discharges from WWTP
- Scenario 51: 90/10 Environmental flows from Warragamba Dam, 2050 land-use and 2050 discharges from WWTP.

2.2 Methodology for the assessment of data in this report

The water quality data for the selected surrogate events was identified, collated and analysed. This data was taken four weeks after the events ended and was selected as typical wet weather quality data in Lake Burragorang. Water quality was assessed up to a depth of 18 metres at monitoring location DWA2.

The surrogate events were validated as representative of normal water quality values and assumed to be normally distributed. The student's t-statistic[1] was used to analyse the difference in the mean of the different quality values (see Table 1). The t-statistic is based on:

- a two-tailed distribution
- a two-sample equal variance (homoscedastic).

Winter 1998 post-event data was compared to data for winter 2007 post-event data and summer 2012 post-event data was compared to a similar event in summer 2010 from water monitoring location DWA2, at up to 18 metres depth in the water column. The validation data was collected over the period 15-17 July 2007.

[1] in statistics, a method of testing hypotheses about the mean of a small sample drawn from a normally distributed population when the population's standard deviation is unknown.

3 Results

Presented in Table 1 are the mean values of key parameters for the winter 1998 post-event water quality (proposed surrogate event) and winter 2007 which had similar water levels and antecedent rainfall conditions. The 1998 event had substantially higher mean total nitrogen concentrations, high total phosphorus concentrations and lower turbidity than the 2007 event.

The Student's t-statistic was used to analyse the difference in the mean of the different quality values (refer Table 2). The Student's t-test shows that all parameters are significantly different between the two events (p<0.05). Apart from turbidity, the 1998 event had significantly higher nutrient concentrations and therefore the 1998 event was a conservative estimate of nutrient concentrations. Turbidity was significantly lower in the 1998 event compared to the 2007 event, however the mean turbidity of the 2007 event, while higher than the 1998 event, was substantially lower than turbidity measured at downstream sites.

Table 1. Mean concentration of post-event winter water quality for 1998 event and 2007 event

Parameter	1998	2007
Total nitrogen (mg/L)	0.37	0.24
Total phosphorus (mg/L)	0.008	0.006
Turbidity lab/field NTU	1.9	5.2

Table 2. Outcomes of t-test comparing mean values of key parameters for the 1998 and 2007 events

	Nitrogen total	Phosphorus total (p-value)	Turbidity (p-value)
1998/2007	0.01	0.01	<0.01

The 2012 summer post-event data was compared to a similar event in summer 2010 (see Table 3). No t-test was undertaken as nutrient and turbidity levels in the 2012 post-event were either higher or the same as the 2010 post-event and therefore using the 2012 data was a conservative assessment of water quality in the flood mitigation zone.

Table 3. Post-summer event water quality validation – 2012 compared to normal summer months

Constituent	2012	2010
Nitrogen total (mg/L)	0.40	0.25
Phosphorus total (mg/L)	0.025	0.0025
Turbidity lab/field NTU	7.0	2

Presented in Table 4 to Table 7 are pre and post-event water quality at monitoring location DWA2 for the 1998 winter rainfall event and 2012 summer event. The tables also contain the relevant guideline value (ANZECC 2000) for each parameter and where the guideline value is exceeded the cell has been shaded red. Generally, the concentrations of key parameters were higher post-event compared to pre-event, suggesting that runoff from the catchment was impacting on water quality. However, in the upper water column increases in concentrations was relatively minor. Deeper in the water column the increase in concentrations was much higher, indicating the catchment inflows had entered the reservoir at the bottom of the water column rather than the surface. This typically occurs as winter inflows are colder and denser than the reservoir water.

Table 4. Pre-event water quality data - 1998

Site	Depth	Chlorophyll-a (ug/L)	Total nitrogen (mg/L)	Phosphorus filterable (mg/L)	Total phosphorus (mg/L)	pH (lab/field)	True colour at 400 nm	Turbidity lab/field (NTU)
Guideline		**5**	**0.350**	**0.005**	**0.0100**	**6.5 to 8.0**		**1 to 20**
DWA2	0	1.72	0.248	0.003	0.0044	Not available	Not available	Not available
DWA2	3	1.42	0.248	0.003	0.0048	7.2	3.5	0.99
DWA2	6	1.44	0.254	0.003	0.0042	7.4	5	0.96
DWA2	9	1.38	0.258	0.003	0.0042	Not available	Not available	Not available
DWA2	12	1.39	0.255	0.003	0.0043	Not available	Not available	Not available
DWA2	18	Not available	0.253	0.002	0.0043	7.3	4	0.86
DWA2	24	Not available	0.21	0.003	0.0040	7.3	4	0.92
DWA2	36	Not available	0.334	0.003	0.0044	7.1	4.5	0.94
DWA2	48	Not available	0.31	0.003	0.0044	7.1	4.3	1.10
DWA2	78	Not available	0.336	0.004	0.0050	7.0	5.3	1.69

Table 5. Post-event water quality data - 1998

Site	Depth	Chlorophyll-a (ug/L)	Total nitrogen (mg/L)	Phosphorus filterable (mg/L)	Phosphorus total (mg/L)	pH (lab/field)	True colour at 400 nm	Turbidity lab/field (NTU)
Guideline		5	0.35	0.0050	0.0100	6.5 to 8.0		1 to 20
DWA2	0	2.53	0.31	0.0035	0.0070	NA	Not available	Not available
DWA2	3	3.20	0.37	0.0035	0.0080	7.34	5.00	2.13
DWA2	6	3.16	0.60	0.0045	0.0085	Not available	4.00	1.26
DWA2	8	2.03	0.31	0.0050	0.0075	Not available	5.00	1.11
DWA2	12	1.25	0.33	0.0035	0.0080	Not available	6.14	1.50
DWA2	18	Not available	0.32	0.0030	0.0065	7.30	5.33	2.01
DWA2	24	0.70	0.40	Not available	0.0085	Not available	5.25	1.95
DWA2	33	Not available	0.49	Not available	0.0100	7.13	12.78	12.11
DWA2	36	Not available	0.45	0.0060	0.0090	7.09	9.50	5.48
DWA2	48	Not available	0.57	0.0065	0.0150	7.02	10.33	8.23
DWA2	78	Not available	0.85	0.0100	0.0400	6.87	26.00	44.45

Table 6. Pre-event water quality data - 2012

Site	Depth	Chlorophyll-a (ug/L)	Total Nitrogen (mg/L)	Phosphorus Filterable (mg/L)	Total Phosphorus (mg/L)	pH (Lab/Field)	True Colour at 400nm	Turbidity Lab/Field (NTU)
Guideline		**5**	**0.35**	**0.005**	**0.0100**	**6.5 to 8.0**		**1 to 20**
DWA2	0	3.46	0.30	0.001	0.003	7.90	6.7	1.5
DWA2	6	2.76	0.30	0.001	0.003	7.76	6.7	1.8
DWA2	9	1.66	0.32	0.001	0.003	7.75	7.0	0.8
DWA2	12	1.13	0.36	0.001	0.003	7.60	8.0	2.5
DWA2	18	1.03	0.37	0.001	0.003	7.53	7.3	2.3
DWA2	24	Not available	0.39	0.002	0.003	7.48	8.0	1.5
DWA2	36	Not available	0.40	0.002	0.003	7.42	8.0	1.6
DWA2	48	Not available	0.41	0.002	0.005	7.36	7.7	3.5
DWA2	60	Not available	0.42	0.002	0.007	7.31	7.7	6.1
DWA2	84	Not available	0.41	0.003	0.017	7.25	9.7	14.9

Table 7. Post-event water quality data - 2012

Site	Depth	Chlorophyll-a (ug/L)	Total Nitrogen (mg/L)	Phosphorus Filterable (mg/L)	Total Phosphorus (mg/L)	pH (Lab/Field)	True Colour at 400nm	Turbidity Lab/Field (NTU)
Guideline		**5**	**0.35**	**0.0050**	**0.0100**	**6.5 to 8.0**		**1 to 20**
DWA2	0	3.95	0.28	0.0024	0.0090	7.37	12.6	2.5
DWA2	6	3.85	0.31	0.0021	0.0106	7.29	15	4.2
DWA2	9	2.1	0.47	0.0040	0.0220	7.23	31.5	5.1
DWA2	11	Not available	0.46	0.0050	0.0260	7.20	36	6.0
DWA2	12	1.65	0.42	0.0036	0.0200	7.19	26.6	7.0
DWA2	17	Not available	0.47	0.0040	0.0230	7.07	31	11.4
DWA2	18	0.65	0.49	0.0066	0.0246	7.07	32	11.0
DWA2	24	Not available	0.37	0.0028	0.0085	7.09	12.8	5.7
DWA2	36	Not available	0.35	0.0015	0.00525	7.22	8	4.1
DWA2	48	Not available	0.36	0.0018	0.0043	7.18	8.8	4.4
DWA2	60	Not available	0.37	0.0030	0.0085	7.18	8	5.9
DWA2	89	Not available	0.37	0.0030	0.0115	7.12	8.5	8.8

4 References

Australian and New Zealand Environment and Conservation Council & Agricultural and Resource Management Council of Australia and New Zealand 2000, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality, National Water Quality Management Strategy Paper No. 4*, ANZECC & ARMCANZ.

Department of Environment, Climate Change and Water 2006, *NSW Water Quality and River Flow Objectives – helping to consider community values for water quality in decision making*, DECCW[2].

Sydney Water (2016), *Hawkesbury Nepean analysis toolkit*, Sydney Water.

[2] https://www.environment.nsw.gov.au/ieo/

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