10. Water quality

This chapter addresses the following Director-General requirements relating to water quality impacts:

- Impact to water quality and how it would be managed during construction and operation of the project;
- Assess the potential for salinisation of the River Murray and associated waterways as a result of the project's operation including implications on the productivity of the Murray River and subsequent mitigation and/or management measures.

This chapter summarises the main findings of the water quality report included in Appendix E.

10.1 Existing environment

10.1.1 Water quality

Data on key water quality parameters has been summarised in Table 10-1 for two sites, one on the Wakool River at a site well downstream of the project area, and one on the Murray River. Data are presented as the median values together with the 25^{th} and 75^{th} percentile values to give an indication of the range. N.A. indicates data not available. Table 10-2 shows results for existing water quality data from these sites. Values are compared against ANZECC (2000) trigger guidelines.

The Murray River sites show a general trend of decreasing water quality downstream with nutrient levels, turbidity and salinity all increasing downstream of Torrumbarry Weir. Oxygen levels are variable, presumably reflecting the impact of primary production in the channel, since algae produce oxygen during the day as a by-product of photosynthesis.

The Wakool River results are not substantially different from the Murray River, although turbidity levels are higher in the Wakool River. Dissolved Organic Carbon (DOC) levels are also slightly higher in these two tributary streams, and nutrient levels are also relatively high.

Table 10-1 Default trigger values for physical and chemical water quality stressors in southeast Australia[3].

Parameter	ANZECC (2000) (2000) Guideline Value	Murray River (Torrumbarry)	Murray River (Wakool)
Dissolved Oxygen (mg/L)	85 to 110%	9.4[4] = 110%	9.1
Chlorophyll (ug/L)	5	14	No data
DOC (mg/L)	No data	4	No data

[3] Values given are for a lowland river.

[4] Conversion from mg/L is based on the assumption of altitude at Koondrook (71m) and an average water temperature of 23 degrees Celsius.

Parameter	ANZECC (2000) (2000) Guideline Value	Murray River (Torrumbarry)	Murray River (Wakool)
Turbidity (ntu)	6 to 50	18	32
Conductivity ms/cm	125 to 2,200	110	250
Total Nitrogen mg/L	0.5	0.45	0.58
Total Phosphorus (mg/L)	0.05	0.061	0.075
pH	6.5 to 8.0	No data	No data

The guideline values are designed to trigger a management response be it either continued environmental monitoring or remedial action to determine whether an environmental problem exists. This would be the case for Total Nitrogen and Phosphorus were baseline values are slightly elevated above the ANZECC trigger guideline values.

10.1.2 Overview of algal blooms in the Murray-Darling basins

In inland waters, blooms of cyanobacteria (blue-green algae) have been known to cause kills of aquatic organisms through depletion of dissolved oxygen in the water either through respiration processes which predominate at night, or through decomposition of dead cells. A number cyanobacterial species also produce toxins which can kill both aquatic organisms and, potentially, terrestrial animals, including humans, that drink the water. Phosphorus and nitrogen are the two major nutrients required by algae and other plants. A number of cyanobacteria have the ability to fix nitrogen gas, rather than depending on other forms of soluble nitrogen such as the oxides of nitrogen. As a consequence, cyanobacteria tend to be favoured when phosphorus is abundant in aquatic systems, but when nitrogen is in shorter supply.

Within the Murray-Darling basin, an intense toxic cyanobacterial bloom stretching over 1,000 km of the Darling River in the summer of 1991-2 (GHD 1992) triggered a state of emergency in NSW and focussed public attention on nutrient enrichment of Australian inland waters. The MDBC had already commissioned a consultants report on nutrient sources in the basin (GHD 1992) and subsequently developed an algal management strategy (MDBC 1992).

The MDBC algal management strategy identified high nutrient levels, calm water conditions and degraded aquatic ecosystems as the three most important conditions contributing to algal blooms in the Murray-Darling (MDBC 1994). Consequently, the management strategy focussed on nutrient reduction and provision of environmental flows as the physical objectives to reduce bloom incidence.

ANZECC (2000) identified trigger values for nutrients in slightly disturbed westward flowing lowland rivers in southeastern Australia as outlined in Table 10-2. These are the values below which algal blooms would not generally be expected.

Table 10-2 ANZECC (2000) identified trigger values for nutrients in slightly disturbed westward flowing lowland rivers in southeastern Australia

Parameter	Chl *a*	TP	FRP	TN	NO_x	NH_4^+
Unit	µg L^{-1}	µg P L^{-1}	µg P L^{-1}	µg N L^{-1}	µg N L^{-1}	µg N L^{-1}
Trigger Value	5	50	20	500	40	20

Since the development of the MDBC strategy, research has been undertaken within the rivers of the Murray-Darling basin to attempt to understand the factors responsible and to quantify or model the factors that can lead to algal blooms.

Grace *et al.* (1997) concluded that phosphorus was probably not the critical factor in triggering the algal bloom in the Darling River, and other researchers have concluded that physical factors play a key role (e.g. Mitrovic *et al*. 2003, Westwood and Ganf 2004). Davis and Koop (2005) identify stratification and light penetration, rather than nutrient availability, as the triggers for bloom formation in the impounded rivers of southeastern Australia, although nutrient exhaustion limits the biomass of blooms. They consider that nitrogen plays as important a role as phosphorus does in controlling the biomass of these freshwater blooms.

Turbidity

Turbidity is the measure of suspended sediments within a water body such as a river or stream. Sediments generally come from either point sources (pipes) or non-point sources (agricultural fields) in the form of run-off.

Turbidity in the River Murray increases downstream from Torrumbarry Weir to downstream of the Wakool Junction, but none of the values are considered to be high (refer to Table 10-1). Nutrient levels also increase, and it is likely that the increase in turbidity reflects, at least in part, an increase in suspended algae. The river would also accumulate suspended particulate organic material from terrestrial sources.

10.1.3 Blackwater events

10.1.4 Overview of blackwater events

Blackwater events have been defined as events which have elevated levels of dissolved organic carbon in the water sufficient to give the water a dark colour that is associated with low levels of dissolved oxygen in the water column that cause fish kills. The oxygen levels are lowered when oxygen is used by microbes in suspension as they metabolize the organic carbon.

There have been a number of blackwater events in the Murray-Darling basin, of which the most serious was the event following the artificial flooding of the Barmah-Millewa Forest in 2000. This resulted in blackwater returning to the Murray River and causing fish and crustacean kills downstream (Baldwin et al. 2001). A subsequent artificial flooding at the same location in 2005/6 appears not to have resulted in a fish kill (O'Connor et al. 2007) although it did cause changes in river water colour (DIPNR 2005). The main source of dissolved organic carbon appears to be River Red Gum leaves, rather than wood or bark (Francis and Sheldon 2002).

The key issue of concern arising from blackwater events is the low concentration of dissolved oxygen which occurs on the floodplain, but can also occur in channels downstream. In this case that could mean the Murray, Barber Creek or the Wakool River. There are a range of processes potentially influencing the dissolved oxygen concentration of water on the floodplain, and these are illustrated in the conceptual model in Figure 10-1.

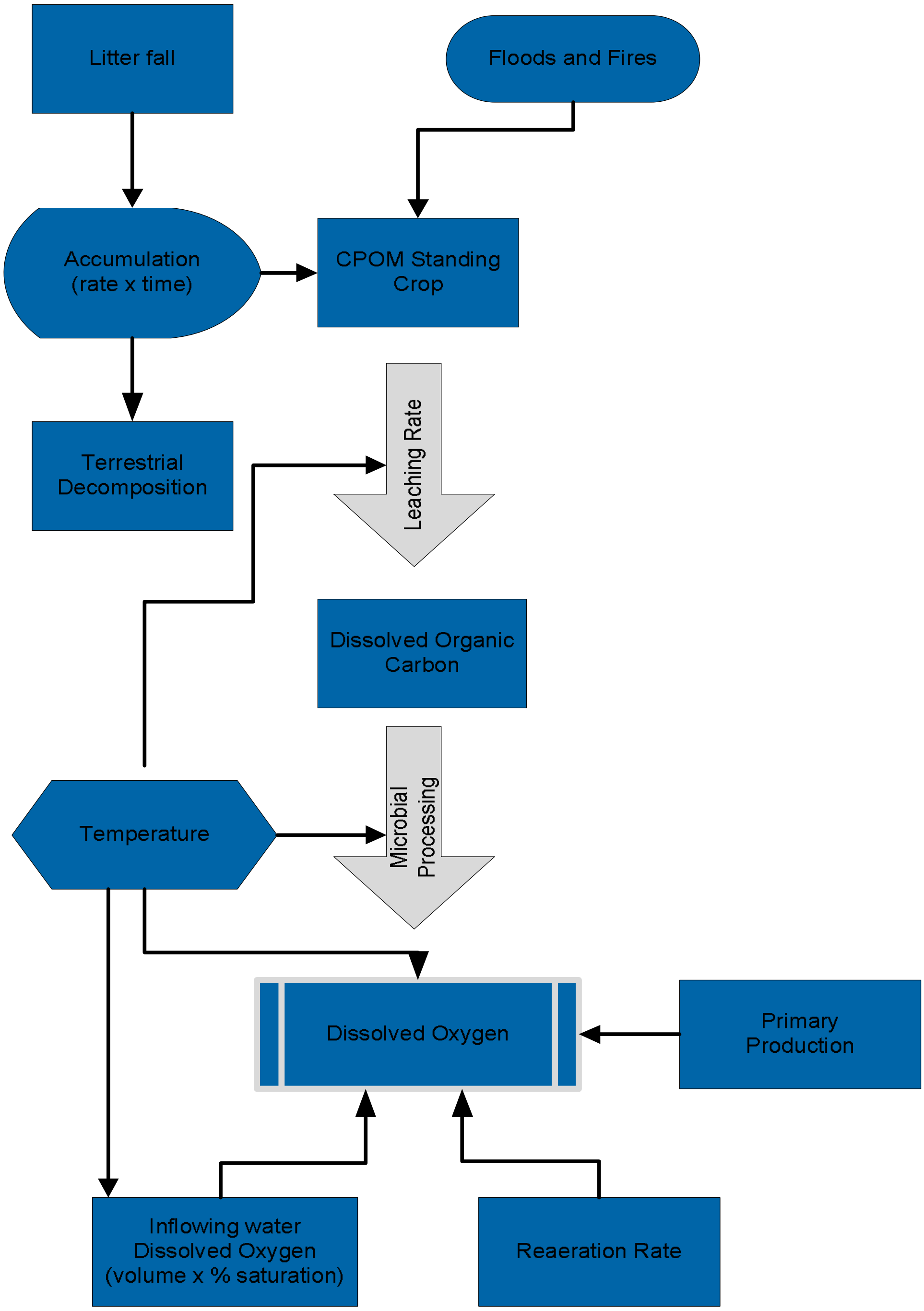

Figure 10-1 Flow chart of issues related to blackwater events

Standing crop of plant litter

The main source of dissolved organic carbon is River Red Gum leaf material, so a key variable influencing the concentration of dissolved organic carbon is the standing crop or amount of

River Red Gum leaf material present on the floodplain. The standing crop is highly variable both spatially and temporally. Glazebrook and Robertson (1999) cite dry mass levels prior to autumn and winter floods at two sites in the Barmah-Millewa forest, which is also a River Red Gum forest and only about 50 km from Koondrook-Perricoota, ranging from 53 to 228 g/m^{-2}, and total plant litter ranging from 495 to 2,350 g/m^{-2} – in each case a four fold difference. The spatial variation occurs because the trees shedding the litter are not evenly distributed, and because the material dropped is redistributed by wind and water, accumulating more in depressions such as flood runners, and against obstructions such as branches. At a larger scale, the presence of other vegetation types and areas which have been cleared or partly cleared by logging or fire would alter rates of litter accumulation and thus different standing crops.

The standing crop of plant litter also varies temporally. Glazebrook and Robertson (1999) found higher standing crops in autumn than in winter, presumably because the peak litter fall occurs in summer in temperate eucalypt forests (e.g. Campbell *et al.* 1992). Shed material decomposes on the ground with standing crop decreasing from the end of the summer peak once the rate of litter fall falls below the decomposition rate. Over longer time periods, the standing crop tends to increase year by year unless it is reduced by a fire or flood. Eventually the standing crop reaches a level where the annual rate of decomposition is equal to the rate of litter fall, although that is probably rare in these relatively dry forests.

Floods influence litter standing crop in two ways: wash out and decomposition. Where the flood results in substantial water movement, plant litter loose on the ground may be transported and redistributed by the water. In addition, leaf decomposition is more rapid in the water than terrestrial decomposition. Glazebrook and Robertson (1999) estimated that during flood periods there would be a net loss of leaf litter standing crop of about 14 kg ha^{-1} day^{-1} in autumn and about 10 kg ha^{-1} day^{-1} in winter due to decomposition processes exceeding litter-fall rates.

Decomposition rates of plant litter influence the standing crop that is present when a forest floods. The factors influencing the decomposition process include temperature, water chemistry and the size of the litter accumulations. At higher temperatures, the decomposition is faster, partly because the speed of solution of dissolved organic carbon is more rapid, and partly because the other breakdown processes, which are microbially mediated, speed up. Higher nutrient levels, and especially nitrogen concentrations, in the water speed up processing rates, presumably through their influence on microbial growth rates (Webster and Benfield 1986). The size of the litter accumulation also influences decomposition rate because as the leaves form large packs, the relative surface area exposed to the water is reduced (Campbell *et al.* 1994).

Concentrations of dissolved organic carbon and dissolved oxygen

The concentration of dissolved organic carbon in the flood water depends on the standing crop of leaf and other plant litter material, and on the leaching of organic compounds from the plant litter. The leaching process generally follows a negative exponential pattern, with a rapid rate of initial leaching which slows over time as the most water soluble materials are most rapidly leached to leave behind the less soluble material.

The rapid initial leaching of dissolved organic carbon usually results in leaves losing 10-20% of their biomass within the first 24-48 hours of immersion in water. The speed of leaching is important because it means that even if the first flood in the forest is “flushed through” it would still have the potential to accumulate a substantial concentration of dissolved organic carbon.

The concentration of dissolved oxygen in the floodplain waters at any given time would depend on a number of factors. The first is temperature. The solubility of oxygen is inversely related to temperature, so the concentration of oxygen in the water would be lower in summer than winter, and oxygen related fish kills would be more likely to occur in summer, particularly on hot days.

The final concentration of oxygen in water on the flood lain would be influenced by the oxygen concentration in the incoming water. In the absence of an algal bloom which would reduce the night time concentrations and elevate the day time concentrations, the concentration would probably be close to saturated. On the floodplain, the temperatures may rise in summer as the water flows over warm soils, resulting in a lowering of dissolved oxygen.

As bacteria in the water begin to utilise the dissolved organic carbon which has leached from the leaves, they utilise dissolved oxygen and reduce it. The rate at which dissolved organic carbon is metabolised is temperature dependant.

While bacterial metabolism would utilise dissolved oxygen in floodplain waters, algal photosynthesis would increase it, at least during the day. The levels of oxygen producing primary production would depend on a range of factors including water temperature and light availability. Thus they would be higher in summer than winter, and would be lower in flooded areas where forest canopy is denser and the water is shaded. Dissolved organic carbon released from the plant litter which colours the water would also reduce primary production by reducing light penetration.

If the oxygen concentration in the floodplain water drops below the 100% saturation concentration for the particular temperature, physical reaeration processes would commence to replenish the dissolved oxygen. The rate at which reaeration occurs would depend on physical factors such as wind speed, with reaeration rates increasing on windy days, and also on whether the water stratifies to form layers with little mixing between them. Under those conditions, the upper water layers may have high oxygen concentrations while the lower strata remain deoxygenated.

10.2 Impact assessment

Four main potential water quality impacts have been identified relating to the project. These are turbidity issues arising from construction sediment or erosion within the forest, possible salinity issues arising from saline groundwater or soils, blooms of potentially toxic blue-green algae (Cyanobacteria), and blackwater events triggered by leaching of organic material from plant litter accumulated on the forest floor.

As discussed in Section 6.4, the project would be operated in accordance with an Operating Plan that would be underpinned by a comprehensive ecological monitoring program. The function of this monitoring program would be to provide information required to assess the ecological response of the Forest to each watering event, so that the effectiveness of the event can be evaluated and lessons can be applied to subsequent events. Over time, it is expected that this approach would lead to a reduction in adverse impacts on water quality because the response of the system would be understood to a higher degree. This is fundamental to the principles of adaptive management upon which the Operating Plan is based.

The following section assesses the potential construction and operational impacts of the project on water quality.

10.2.1 Turbidity

Overview of the impact

There is extensive published literature available on the effects of suspended particulate material on running waters (Campbell and Doeg 1989, ANZECC 1992, ANZECC 2000). The usual impacts include a reduction in light penetration reducing primary production, interference with feeding by visual predators and filter feeders, and smothering and modification of habitat for bottom dwelling organisms. Essentially the extent of the impact depends on the amount of sediment generated and the length of time over which it is generated.

Within floodplain river systems water movement over the floodplain is often slow, and sediment tends to be deposited rather than eroded.

Impact assessment

There is potential for sediment to be generated in the creek channels, through bank erosion, from construction sites if bare soil is left exposed, and from other areas where bare soil is exposed, especially if fine sediment has accumulated through the activities of humans or stock. The project has the potential to lead to elevated turbidity levels during both the construction and operational phases.

In general, risks to water quality from sediment are considered of low consequence because much of the transported sediment would be deposited within the Forest during the period while the water is retained and thus would have little impact on the river downstream. The Forest would be a net sediment trap rather than a sediment source. The impact of erosion from construction sites is likely to be short term, and only contribute to downstream turbidity where the source is near the discharge point.

Implementation of appropriate construction site environmental management plans would ensure that sediment delivery to the system from erosion at construction sites is limited in extent and duration. During operation, erosion along creek channels would be minimised by adaptively managing the flow regime to maintain low water velocities, and erosion from elsewhere in the Forest could be controlled by managing stock and areas intensively used by humans.

10.2.2 Salinity

The risk of the project substantial increasing salinity in the river is considered to be low. Previous assessments of the risk of salinisation from groundwater have concluded that the Forest area appears to be primarily a groundwater recharge area rather than a discharge area (Evans and Barnett 2007, Salient Solutions 2008). Consequently there is little risk of the seepage of saline groundwater from the area entering either the Murray River or other streams in the area. Salt wash off is likely to be responsible for the delivery of salt loads returning to the surface water as a result of forest flooding (Salient Solutions 2008).

In addition, construction would not involve excavations beyond five metres below ground. As typical groundwater depths in the Forest are between seven and twelve metres below ground, groundwater is unlikely to be impacted during construction.

10.2.3 Blue-green algae

Factors that would influence occurrence of algal blooms

Whether cyanobacterial blooms occur in the Koondrook-Perricoota forest during watering events would depend on a number of critical variables including the timing of the flood, the retention period and water quality. The time of year of the flood is important because warmer temperatures would favour stratification, and light availability is greater in summer. The retention period is important because longer retention periods favour algal growth as stratification develops in the pool. Stratification, with deoxygenation of the deeper water, would lead to increased nutrient release from the sediments and would tend to promote algal growth. As stratification develops in summer when water temperatures are higher, and at times when water turbulence is low, it is more likely to occur when water is pooled rather than flowing through the forest, and in areas sheltered from the wind or on calm days. It is also more likely to develop and persist in deeper rather than in shallow water

Water quality parameters that would be important in influencing algal growth include nutrient concentrations, which would influence the size of the algal standing crop, and the ratio of phosphorus to nitrogen, with higher relative phosphorus levels tending to favour cyanobacteria many of which can fix atmospheric nitrogen. Light penetration into the water would be influenced by the colour of the water and level of turbidity. Shading by the forest would also tend to reduce the potential for blooms by reducing light availability.

Nitrogen and phosphorus levels in the Torrumbarry Weir pool

Data on water quality are available for Torrumbarry Weir which is close to the inflow point for the project, and so is representative of the water that would be used to flood the Forest. Both nitrogen and phosphorus are sampled weekly, and data since January of 2004 have been analysed. This time period was selected because it was sufficiently long (5.5 years) to give a meaningful data set that is representative of current conditions at the site. Median total Phosphorus (P) concentration was 36µg L^{-1} while the 75th percentile level was 47 µg L^{-1}. These values are below the ANZECC and NSW trigger values, but exceed the Victorian trigger value which is 32 µg L^{-1}.

Median total nitrogen was 370 µg L^{-1} with a 75th percentile value of 460 µg L^{-1}. The median value is below the ANZECC, NSW and Victoria trigger values, but the 75th percentile value exceeds the Victoria trigger which is set at 422 µg L^{-1}.

Likelihood of blue-green algae blooms forming

Based on the nutrient values in the Torrumbarry Weir pool outlined above, the quality of water quality is unlikely to lead to cyanobacterial blooms forming in the Forest during operation of the project. However, the nutrient levels are elevated, so management activities such as intensive grazing resulting in accumulations of animal manure could be sufficient to raise nutrient concentration above trigger levels, thereby increasing the risk.

The effect of light availability is more difficult to predict because it is influenced by shading, for which data is not available, and by colour of the water. Water colour would be influenced by leaching of materials from the plant litter inundated within the forest. The greater the colouration of the water, the more likely there would be blackwater events and the less likely there would be algal blooms. For the initial floods, the levels of colour are likely to be high and thus the risk of algal blooms would be low. If subsequent floods occur only every three years, there is likely to be sufficient accumulation of plant litter to ensure that dissolved organic carbon levels, and thus water colour, is also high for future flood events, and the risk of algal blooms within the inundation area would not increase.

10.2.4 Blackwater events

Potential issues in the Forest and downstream waterways due to operation of the project

Blackwater issues may arise both on the inundated floodplain and in downstream channels. The extent to which they occur in downstream channels would depend on the dilution of the released blackwater in the receiving channel, and the concentration of dissolved oxygen in the receiving water, which would depend on the water temperature.

When the first enhanced flood is conducted at the Forest, high concentrations of dissolved organic carbon would accumulate in the water because, in the absence of floods for some years, there would be a substantial accumulation of plant litter on the floodplain. The extent to which this creates a blackwater event would depend mainly on the temperature. If the flooding occurs in cold weather, sufficient concentrations of oxygen are likely to remain in the floodplain water to avoid fish kills.

Whether the return of blackwater to the Murray River, the Wakool and other channels causes an environmental issue would also depend on the season and river conditions at the time of release. For the Murray, the release of blackwater is least likely to create an issue if it occurs when river water levels are high because this would maximise the dilution potential and also river turbulence which enhances reaeration. Returning the floodwater when water temperatures are cold would also lessen the risk of fish kills, because dissolved oxygen concentrations in both the released water and the river would be maximised. However, if the floodplain water is released when water temperatures are high and river flows are low, fish kills are far more likely.

In Barbers Creek, the Wakool and other river channels, the impact of releases would be more complicated. In some cases, these channels have not received flows for some years, and so contain large standing crops of plant litter which would add to the dissolved organic carbon levels already present in the released water. In the case of the Wakool, a number of the pools downstream contain water of very poor quality as a result of litter leachates, salinity and acid sulphate soils. The lack of flows in recent years has meant that this poor quality water is likely to have concentrated rather than been flushed out. Consequently, the first flush of material down these systems is likely to be very poor quality water, and may trigger fish kills in any pools which still support fish and also in the main river channel. This risk would be greater if the release occurs at a time when water temperatures are high.

Blackwater modelling

Blackwater events were modelled for the project using a model adapted from the one developed by Howitt et al. (2007) to predict the occurrence of blackwater events at Barmah-Millewa. The model was adjusted so the hydrological inputs to reflect the operational scenario for the project. It was assumed that ecological parameters such as leaf litter accumulation rates do not differ between Barmah and Koondrook-Perricoota.

The key inputs and limitations of the model are described in Appendix E. One of the key inputs to the model is the standing crop of leaf and other plant litter on the forest floor as this is the ultimate source of the dissolved carbon that causes the blackwater. The model derives an estimate of the litter standing crop from estimates of the seasonally adjusted rates of litter fall and litter decomposition in Millewa Forest as measured by Glazebrook and Robertson (1999) and the time since the previous flood. For simplicity it is assumed that each flood removes all previous accumulated litter. The advantage of this method of determining litter standing crop is that the only data inputs required are the dates of the previous flood, and the date of the next flood. This allows predictions to be made well in advance.

The reason for using litter fall rates rather than direct measures of litter standing crop as the input that model uses to estimate standing crop is to allow the model to be easily operated to compare the effects of differing interflood periods. It has been suggested that the litter standing crop in Barmah is likely to be considerably higher than that in Koondrook because of the forest watering in Barmah. That may be true, however the measurements from Barmah were taken in 1997, when Barmah was drier than now, and in the absence of flooding Koondrook has had about 12 years to accumulate litter load. The model has been run for several time intervals since the previous flood, which has the effect of testing the sensitivity to pre-existing litter load. The longest period to the previous flood was set at 30 months, because of concerns that Koondrook has a lower litter accretion rate.

The model has been run with scenarios including the managed flood commencing on the first of each month from August through to December, and assuming the previous flood ended at the end of January in the same year as the flood, the year prior to the flood and two years prior to the flood.

The key output parameter is the dissolved oxygen concentration, which can trigger fish kills if it drops below about 2 mg/L. For most of the scenarios, dissolved dropped below this level either in January or February as water temperatures rose, or where there had been no prior flood for two years, so there were higher amounts of accumulated organic material on the floodplain to leach dissolved organic carbon. As a result, the seasonality of flood events is considered to be the main factor determining whether a blackwater event is likely to occur.

The importance of the seasonality of flooding is reflected in Section 6.4 and the Operating Plan (Appendix B). The project would specifically target winter and spring flood events as there is a lower risk of water quality impacts associated with both blackwater events and blue green algae blooms occurring at this time of year.

The model did not allow predictions of downstream impacts on the Murray River from releases via the return channel or Barber Creek/Wakool system. When the return channel is operating at maximum flow rates of 1,850 ML/day, flows in the Murray River downstream of the Torrumbarry Weir are likely to be at least 5,000 - 6,000 ML/day. As a result, blackwater would be diluted by flows in the Murray River.

If blackwater is released down Barbers Creek at the maximum rate of 250 ML/day, it would flow approximately 58 km downstream before being diluted by the Wakool River which is likely to have flows in the order of 500 – 600 ML/day at the time of year the project is likely to operate. If flows from the Merran Creek system are entering Barbers Creek upstream of the confluence with the Wakool River, this would assist in diluting blackwater.

Impact on town drinking water

Concern has been expressed about the consequences of blackwater releases for drinking water supplies for townships downstream. Blackwater colour is caused by tannins and other chemicals leached from leaves, in the same process used for making tea. The material is not considered dangerous to the health of humans or other animals if it is consumed and it is not a material of concern in the Australian Drinking Water Guidelines. Similarly, the reduction in dissolved oxygen which could occur as a result of a blackwater event is not a health hazard for humans or terrestrial animals, so it does not pose a risk to drinking water supplies. If the colour is too intense it may cause concern amongst consumers used to colourless water supplies, but this can be managed by ensuring adequate dilution by passing flows from Torrumbarry.

As far as can be determined, towns downstream which would be potentially exposed to blackwater have activated carbon water treatment which would remove the coloured dissolved organic carbon from water (along with other organic contaminants).

10.2.5 Chemical spills

Chemicals such as fuels would be stored in the construction compounds during the construction period and spills from storage facilities have the potential to contaminate soil and water. As described in Section 6.3.10 and 6.3.11, the contractor would operate within the requirements of the *Occupational Health and Safety Act 2000* and AS 1940-2004 *"The storage and handling of flammable and combustible liquids"* when storing, transporting, handling, using or dealing with spills of dangerous goods and or agricultural chemicals.

All materials would be transported, used and stored in accordance with the relevant Australian Standard, Material Safety Data Sheets, and the Australian Dangerous Goods Code. In the event of any inconsistencies between these, the most stringent criteria would be applied.

Chemical or fuel spills can have potential impacts on the environment and a range of control mechanisms would be applied to ensure these impacts are minimised. This would involve implementing relevant measures detailed in Forests NSW's *Chemicals Manual* (2006) (including Forests NSW HAZMAT procedure).

10.3 Mitigation and management measures

10.3.1 Construction

Potential impacts associated with turbidity would be managed by implementing measures to minimise erosion and sedimentation. These measures are detailed in Section 11.3.

10.3.2 Operation

There is the potential for operation of the project to impacts on water quality by producing blue-green algae blooms and blackwater events. The likelihood of these events occurring is influenced to a large degree by the seasonality of floods, and they are more likely to occur when flooding occurs over summer as opposed to winter and spring when temperatures are cooler. The most effective mitigation measure to minimise the likelihood of these events occurring would be to avoid holding pooled water within the Forest during the warm months. As detailed in

Section 6.4, operational planning would consider the seasonality of watering events and preference would be given to winter and spring flood events.

A comprehensive water quality monitoring program would be developed and implemented as part of the Operational Plan. This would involve monitoring of surface water quality using ANZECC guidelines as a reference point to allow appropriate management decisions to be made should nutrient and turbidity levels exceed trigger values. The water quality monitoring program would be integrated with other monitoring so that the overall ecological response of the Forest to a flood event can be evaluated, and lessons can be applied to subsequent events.

The Operational Plan would include a procedure to be implemented in the event that blackwater conditions are observed. This would lead to involve a multi-agency coordinated response using the best available scientific information.

Specific mitigation measures for blue-green algae blooms and blackwater events are outlined below.

Mitigation of the risk of blue-green algal blooms

The risk of cyanobacterial blooms is greater in summer than at other times of the year because of the higher water temperature levels and greater light availability. The most effective mitigation measure would be to avoid holding pooled water within the Forest during the warm months.

Secondly any management activities which can reduce the potential for nutrient accumulation and release from the flooded area would help to reduce the risk of algal blooms. Maintaining the condition of the forest understorey, and restricting stock access would be advantageous.

Ongoing land management practices that help reduce the input of nitrogen and phosphorous entering the Forest should be implemented. This should include restricting stock access into the Forest prior to flooding, particularly near watercourses.

Mitigation of the risk of blackwater events

The key mitigation strategy to reduce potential blackwater impacts would be to time the release of the blackwater to periods when water temperatures are low, and if possible, when river flows are high.

Other operational measures may be to increase the frequency of flooding so that there is less litter accumulation on the floodplain between floods, although that option would be constrained by water availability.

It may also be possible to ameliorate the blackwater impact on the main river by aerating the ponded water before release. Aeration systems are widely used in reservoirs and aquaculture systems (e.g. Schladow 1993, Stephens and Imberger 1993) and may be applicable in the Forest. In particular, it may be possible to aerate the area of the flooded forest immediately upstream of the release point thus reducing the impact.

For managed floods, mitigation of effects caused by water discharged via the Murray return channel would be relatively straightforward. The water release could be controlled using the release structure or the volume of water flowing into the forest, or both. In addition the amount of dilution could be controlled by controlling the volume of water passed through Torrumbarry weir.

Water quality monitoring

There is the potential for blackwater events to occur during operation of the project if there are elevated concentrations of dissolved organic carbon and reduced levels of dissolved oxygen. Blackwater has the potential to have a significant impact upon threatened fish and aquatic invertebrate species, populations or the Lower Murray River endangered ecological community.

To ensure the functionality and effectiveness of adaptive management principles that form part of the Operating Plan, the resultant water quality outcomes (relevant to the key parameters of temperature, dissolved oxygen and dissolved organic carbon) would be regularly monitored to qualify and quantify the significance (if any) of the potential impact. The detection and management of such events would also inform the management and operational changes required to mitigate the impact to ensure no significant impact on threatened species.

Monitoring of water temperature, dissolved organic carbon and dissolved oxygen would commence several weeks prior to a flooding event to establish a robust baseline. The monitoring would continue throughout the event and conclude several weeks after the cessation of a flood event.

Monitoring locations would be selected in consultation with NSW Industry and Investment and would include points:

- Upstream of the forest within the Murray River channel;
- Within the inlet channel, downstream of the inlet regulator;
- Within the flooded areas of the forest (approximately 1 site per 1,000 ha flooded and/or key sites to be determined in consultation with NSW Industry and Investment); and
- Upstream and downstream of discharge points into the Murray River, Thule Creek, Barbers Creek and Cow Creek (whichever is discharging during a flood event).

Monitoring would be undertaken prior to, during, and following both managed flood events and would endeavour to include uncontrolled flood events during which the project would not be operated. This would enable water quality impacts during operation of the project to be compared to water quality during flood events when the project is not operated.

Refining the blackwater model

The Operating Plan would include a comprehensive monitoring program that would provide input to a blackwater model developed specifically for the project. The blackwater model developed for the Barmah-Millewa Forest would be customised to provide a more accurate representation of blackwater events in the Forest and enable it to be used as an effective management tool during planning for watering events. The model would be calibrated against controlled flood events to ensure it accurately predicts blackwater events prior to the results being used for routine management purposes

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