Appendix E

Water quality and geomorphology assessment (Cardno)

Macquarie River to Orange Pipeline Project

Water Quality, Geomorphology and Specific Hydrology & Water Use

W4916-R01

Prepared for Orange City Council

31 July 2012

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GLOSSARY

AEP	Annual Exceedance Probability
AHD	Australian Height Datum
ARI	Average Recurrence Interval
BoM	Bureau of Meteorology
DECC	Department of Environment and Climate Change (now NSW Office of Environment and Heritage)
DoP	Department of Planning
GIS	Geographic Information System
ha	hectare
HEC-RAS model	Hydrologic Engineering Center – River Analysis System software package (1 dimensional hydraulic model)
IFD	Intensity Frequency Duration
km	kilometres
km2	Square kilometres
LGA	Local Government Area
m	metre
m2	Square metres
m3	Cubic metres
m3/s	Cubic metres per second
mAHD	Metres to Australian Height Datum
MHWL	Mean High Water Level
mm	millimetre
m/s	metres per second

MSL	Mean Sea Level
NOW	NSW Office of Water
NSW	New South Wales
XP-RAFTS	XP-RAFTS proprietary software package

1 INTRODUCTION

1.1 Purpose of this report

Orange City Council proposes to undertake the Macquarie River to Orange Pipeline Project (referred to in this report as 'the project'). This report has been prepared to provide an assessment of the water quality, geomorphology and specific hydrology and water use impacts of the project as an input to the environmental assessment. The environmental assessment is being prepared in accordance with the requirements of Part 3A of the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act).

The report addresses the requirements of the Director-General of the NSW Department of Planning and Infrastructure (the Director-General's Requirements) dated 24 March 2011.

1.2 Project overview

The project is one step to improving the water security for Orange. It involves construction and operation of infrastructure required to transfer approximately 12 ML/day of water a distance of approximately 37 km from the Macquarie River to the Suma Park Dam at Orange.

The infrastructure required to transfer the water includes an intake and pump stations, an underground pipeline (approximately 37 km in length), a discharge structure, and ancillary infrastructure (power supply).

In summary, the project would involve construction and operation of the following infrastructure:

- 37 km of 375 mm diameter water rising main between the Macquarie River and Suma Park Dam
- An offtake structure and pump station located at the upper Macquarie River
- Two booster pump stations and break tanks along the pipeline route
- Power supply to pumps and other infrastructure
- Telemetry controls to enable remote operation of the infrastructure including pumps and valves etc
- A discharge structure at the Suma Park Dam.

1.3 Project Location

The proposed offtake structure would be located on the south side of the Macquarie River immediately upstream of the confluence with Boshes Creek. The water carried along the pipeline would discharge into the Suma Park Reservoir at Orange via the discharge structure, located approximately 10 m east of the existing saddle dam (at the north-west corner of the dam wall).

Figure 1.1 shows the proposed route for the pipeline, which contains road reserves, including Ophir Road and Long Point Road. In most (up to 70% of the route) areas the pipeline would need to cross private land. It is proposed that the majority of the pipeline would be underground and would not impact on farming or other land uses.

The project would be located in both the Orange and Cabonne local government areas. The majority of the pipeline would be located in the Cabonne local government area (LGA).

1.4 Scope and structure of report

1.4.1 Scope of report

The key objectives of the scope of the analysis presented in this report are as follows:

- The potential risks to surface and groundwater quality during construction and operation activities (including the proposed off take and pipeline infrastructure);
- Determination of the potential geomorphic impacts on the Macquarie River as a result of the off-take structure, and recommend methods in which to mitigate these impacts;
- Determination of the potential geomorphic, erosion and sediment control issues that may result from construction activities in the vicinity of the creek crossings along the pipeline route;
- Potential impacts on Suma Park Reservoir and on the local creeks, from a water quality and geomorphology perspective;
- Estimation of the hydrological flows arriving at each of the creek crossings;
- Include a framework for the mitigation, management and monitoring of surface and groundwater quality impacts during construction and operation including reference to the Managing Urban Stormwater Soils and Construction Volume 1 and Volume 2 (DECC,2008);
- Potential impacts of changes in water quality on the Icely Water Treatment Plant through the pumping of Macquarie River water into the Suma Park Reservoir;

Although the Macquarie River (referred to as “the River”) is the main watercourse examined in this report, several other significant watercourses have been identified and examined. These include:

- Summer Hill Creek
- Boshes Creek
- Oaky Creek
- Kitty’s Creek
- Cow Creek

This report therefore provides advice to GHD in regards to the scope above and addressing the DGR's as identified in Section 1.4.3.

1.4.2 Structure of this Report

This report is divided into a number of sections based on the assessments that have been undertaken. These are outlined below:

- **Section** 2 – Study Area and Background – this section provides an overview of the study area and the key assumptions that have been made in this report in respect to the proposed design;
- **Section** 3 – Available Data – an overview of the data that was supplied to Cardno as a part of this project, and on which the assessments have been based;
- **Section 4** – Hydrology – this section outlines the methodology for delineation of the catchments for each of the crossings and the estimation of the peak flows arriving at each of the crossings;
- **Section 5** – Geomorphology Assessment – this section outlines the geomorphological assessment that was undertaken as a part of this study. It includes an assessment of the off-take within Macquarie River, the creek crossings along the proposed pipeline route and the discharge point into Suma Park Reservoir;
- **Section 6** – Surface Water Quality – this section covers an assessment of the water quality. This includes an assessment of the potential impacts to the creek crossings and reservoir when the pipeline is in operation, as well as the potential impacts during construction;
- **Section 7** – Groundwater – this section, and the report provided in **Appendix C**, provide an overview of the groundwater issues in the study area, which was undertaken by Pells Consulting;
- **Section 8** – Impacts on the Icely Treatment Plant – this section, and the report provided in **Appendix D**, outlines the assessment undertaken by MJM Environmental on the potential impacts on the Icely Treatment Plant from pumping water from the Macquarie River into Suma Park Reservoir.

1.4.3 Where Director-General's requirements are addressed in report

The DGRs addressed by this report are summarised in Table 1.1, together with a reference to where they are addressed in the report.

Table 1-1. Director General's requirements

Assessment Requirements	Where Addressed in Report
Surface & Groundwater Impacts	
Assess the potential risks to surface and groundwater quality during construction and operation activities (including the proposed off-take, pump infrastructure and pipeline maintenance activities), demonstrating that the project can be designed and managed consistent with the principle of a neutral or beneficial effect on water quality in the water catchment; (DoP)	Surface water quality is addressed in Section 6. Groundwater quality is addressed in Section 7.
Include a site water balance clearly identifying and quantifying water use for the project including: annual water demand and sources of input; water reuse and recycling measures; waste water generation and disposal requirements; and stormwater management; (DoP)	Not addressed in this study. To be undertaken by Geolyse.
Address impacts to the hydrological regime and resulting impacts to the environment and existing water users due to operation of the pump. (NoW)	Not addressed in this study. To be undertaken by Geolyse
Include an assessment of potential impacts on other groundwater and surface water users, and the environment under different climatic conditions with details of how existing water access rights will be protected, including with respect to availability, quantity and quality of water in the Macquarie Catchment; (DoP)	Impact assessment undertaken for groundwater users (Section 7). To be undertaken as part of the hydrology and water use study by Geolyse.
Include a framework for the mitigation, management and monitoring of surface and groundwater quality impacts during construction and operation including reference to the *Managing urban stormwater soils and construction volume 1 and volume* 2.(DoP)	Surface water quality is addressed in Section 6. Groundwater quality is addressed in Section 7.
Assess impacts to Groundwater Dependent Ecosystems and groundwater sources, predict dewatering volumes, time period of dewatering, water quality and disposal/retention methods. (NoW)	Groundwater eco-systems considered by Cardno Ecology Lab.
Assess the potential for impacts to watercourses, including the Macquarie River, which are to be impacted by the project, including a risk assessment justifying the proposed construction method depending on stream classification and environmental significance and a strategy for the rehabilitation of any watercourses disturbed by the project to an existing or better standard. (DoP)	Section 5.
Geomorphology and Hydrology	
Identify significant watercourses in terms of hydrological, hydraulic or ecological characteristics or sensitivity and an assessment of the impacts to the stability of these watercourses including the Macquarie River from the construction and operation of the project. The assessment must also include measures to monitor or mitigate any identified impacts during construction and operation; (DoP)	Section 4 provides information on the hydrology of the creeks. Section 5 provides geomorphology assessment and monitoring in Section 6. Note ecological considerations are not included in this report.
Include details of a proposed vegetation or revegetation management plan to ensure that riparian buffer zones are carefully managed (NoW)	Not addressed in this study.

1.4.4 Exclusions

The report covers the surface and groundwater issues as relevant to the scope of works as identified in Section 1.4.1. It is understood that some of the surface and groundwater issues raised in the DGRs will be addressed in complementary reports which are to be prepared by other parties. Specifically, the following issue is not addressed within the scope of this report:

- Ecological issues and appraisals of surface and groundwater dependant ecosystems are not specifically considered, as these are outside the scope of this assessment. However, advice on surface and groundwater presented in this report may be used by qualified ecological specialists to assess these issues.

1.5 Changes to the Pumping Trigger

Advice was provided by GHD on 20 July 2012 that the pumping trigger had been altered from a trigger level of 34ML/day to a trigger level of 38ML/day. It is understood that this is reflective of the need to pump for only 19 hours per day, rather than 24 hours per day.

GHD also provided an analysis of the pumping time series on 20 July 2012, that generally showed little differences in annual pumped flows under the two scenarios. The analysis suggests that pumping occurs under the new trigger 37% of the time, compared with 38% of the time under the old trigger.

Geolyse provided pumping flow times series to Cardno on 26 July 2012. Cardno's analysis of this data set suggests that there is only a minor difference in the number of pumping days over the data set. This difference represents an approximately 1.7% difference in the number of days when pumping occurs.

Given the relative small difference in the number of days where pumping occurs, the analysis undertaken this report has not been updated with the new trigger. The outcomes of Section 6 and 7, which are the sections impacted by this change, would not be impacted significantly by this change. It is also noted, in terms of impacts on the reservoir and the groundwater impacts, that the proposed change in trigger level generally reduces the pumping and as such would improve the outcomes, however negligible.

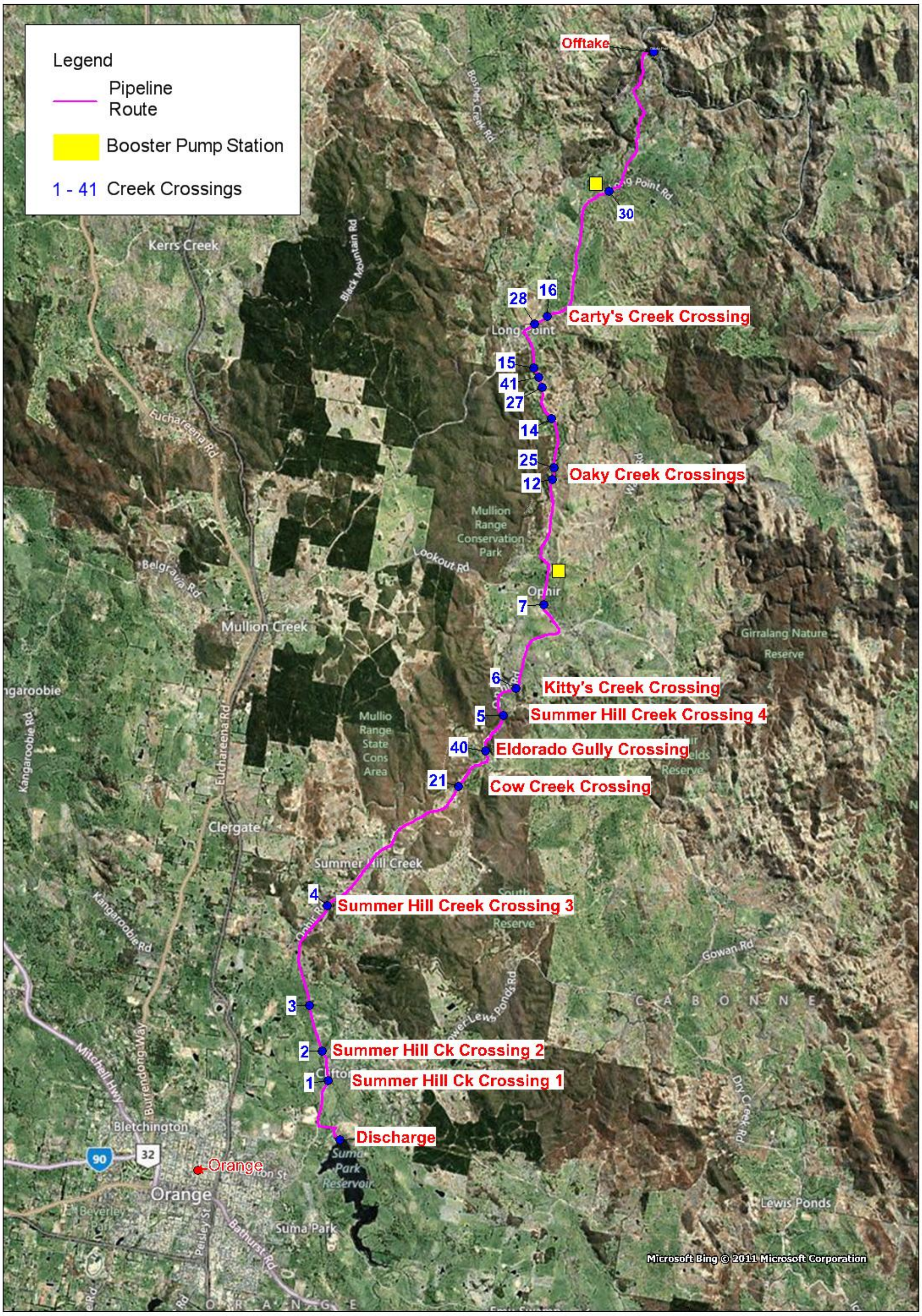


Figure 1-1 The Study Area showing proposed pipeline route, creek crossings and booster pump stations.

2 STUDY AREA AND BACKGROUND

2.1 Study Area

The study area for this assessment extends from the proposed off-take site at the Macquarie River along the proposed pipeline route through to the discharge point into Suma Park Reservoir. This represents an approximate 37 kilometre length of study area. The proposed route for the pipeline is shown on Figure 1.1,

The proposed off-take point would be located north of Long Point on the upper Macquarie River. The proposed off-take point is a location known as Gardiners Hole on the Macquarie River. The impact of the proposed pipeline on the river has been considered in this report through potential impacts on geormorphology and potential scour.

The proposed route for the pipeline, shown in Figure 1.1, includes road reserves, including Ophir Rd and Long Point Rd. In some areas the pipeline would need to cross private land. It is proposed that the majority of the pipeline would be underground and during operation would not impact on farming or other land uses. The majority of the pipeline is located within the Cabonne LGA.

The pipeline route also crosses a number of creeks and drainage points. These have been investigated in this report through the potential impact on water quality and geomorphology.

3 AVAILABLE DATA

3.1 Proposed Pipeline Design Drawings

Concept design drawings for the pipeline were provided by GHD on 19 December 2011 (Orange City Council, 2011, Drawing No 211259_01C_E01-E60, dated 15 December 2011, file name: *211259_01C_E01-E28.pdf* and *211259_01C_E29-E60.pdf*). There are a total of 60 plans showing the proposed alignment of the pipeline.

A concept investigation report for the pipeline was also provided by GHD on 16 December 2011. The report *Orange Drought Relief Connection Concept Investigation Report* (MWH, January 2011), provides information on initial investigations undertaken and alternative routes assessed.

3.2 Water Quality Data

Water quality information for single sampling sites within the Macquarie River and the Suma Park Reservoir were provided to Cardno by GHD on 21 September 2011. Information on several water quality parameters was provided, with sample dates ranging from April 2008 to July 2011. Sample sizes range from 1 to 60 data points, although the majority of parameters tend to have approximately 10-15 measurements. No depth or location of the sampling points was provided and no quality control/ assurance information was available for the data. It has been assumed that the data are reliable for the purposes of this analysis.

A list of the sampled parameters is provided below:

Physico-chemical, Nutrients, Other

- pH
- Electrical Conductivity (EC)
- Total Dissolved Solids (TDS)
- Suspended solids
- Turbidity
- Anions
- Alkalinity
- Dissolved Cations
- Nutrients (Total Nitrogen, Total Phosphorous, Total Organic Carbon)
- Micro-organisms

Toxicants

- Metals (soluble and total)
- Cyanide
- Asbestos
- Monocyclic aromatic hydrocarbons
- Fumigants
- Oxygenated and Sulfonated compounds
- Halogenated aliphatic & aromatic compounds
- Trihalomethanes
- Phenolic compounds
- Polynuclear aromatic hydrocarbons
- Organophosphorous pesticides
- Organochlorine pesticides
- Polychlorinated biphenyls
- Phenoxyacetic acid herbicides

3.3 River Flow Data

Some river flow data was provided with the water quality data described in Section 3.2. Based on the notes within the Excel spreadsheet of information, it would appear that the data was obtained from gauging stations upstream of where the water quality data was collected.

Additional modelled flow data for the Macquarie River was provided to Cardno by Geolyse on 6 December 2011. However, the results of this modelling finish at the end of 2009, while the majority of the water quality samples were collected in 2010 and 2011. Therefore, it is not possible to directly correlate the two data sets.

Geolyse subsequently provided estimates of flow data in the Macquarie River for the 2010 through to 2011 period on 19 December 2011. This was based on available gauge data upstream of the Macquarie River sampling site.

3.4 HEC-RAS Model

A HEC RAS model was prepared by Geolyse for Gardiners Hole using river survey undertaken in October 2011. The model was provided to Cardno on 11th April 2012 and is limited to a 260m reach with the offtake location positioned roughly in the centre of that reach. As such the model was prepared for the purpose of flood level estimation and the use of it for estimating flow depths, velocity and the like are reflective of the model in its preliminary form. The model was calibrated using statistical analysis of river flow data using several gauges along the River. Input flows to the model were provided for the 50%, 5%, 1% and 0.5% AEP.

3.5 Survey Data

The following survey data was provided by GHD:

- Photogrammetry data. This data is confined to a corridor along the proposed pipeline route. The data provides levels along the pipeline route, although details of the in-bank portions of the creeks are limited.
- Survey of the Macquarie River (Geolyse, Drawing Sheet 02A_DS01 to 02A_DS03, dated October 2011, file name: *211108 river bed surveys.pdf*). This information was provided in a CAD format and covers the Macquarie River in the vicinity of the off-take site.

3.6 Site Inspections

Two sets of site inspections were undertaken during the project:

- Initial reconnaissance of the creek crossings within the study area on 2 December 2011;
- Detailed inspection of the off-take, creek crossings and reservoir discharge site on 14 and 15 December 2011.

3.7 Water Balance Model for Suma Park Reservoir

Water balance modelling results were provided by Geolyse on 10 February 2012. This provided information on the various key inputs to the reservoir, the estimated water levels, and the discharges from the reservoir over an approximate 100 year period.

4 HYDROLOGY

The proposed pipeline crosses a number of creeks and drainage lines along the 36km length. An XP-RAFTS hydrological model was established for the study area, to generate hydrographs at key crossings along the pipeline route. The land use within the study area is dominated by rural area, with some small residential areas and the Orange CBD. The following attributes were considered in the hydrological modelling:

- Rainfall intensity-frequency-duration (IFD) relationships;
- Sub-catchment divisions;
- Slopes and overland flowpath lengths; and
- Land use (pervious and impervious areas).

4.1 Sub-Catchment Delineation

Sub-catchment delineation is a preparation step for establishing a hydrological model. The total area for the XP-RAFTS model is 34,500 hectares, with elevation varied from 1,010m AHD in the upper reaches of the catchment to 610m AHD at the catchment outlet.

The study area was divided into 21 sub-catchments based on the topographic features (using 10-metre contour data), the likely flowpaths and the locations of creek crossings. The sub-catchment layout is presented in **Figure 4.1** and the details of these sub-catchments are provided in **Table 4.1**.

Pervious and impervious fractions for each sub-catchment were estimated based on aerial photograph and site inspections. The following impervious fractions were used for different types of landuse.

Urbanised residential:	60%
Rural Area:	5%

The total impervious area is estimated at approximately 3,000 hectares, which represents 8.7% of the total area.

Table 4-1. Sub-Catchment Details

Sub-catchment ID	Area (ha)	Catchment Slope (%)	(%) Impervious	Land Use
C1	7412.4	0.9	5	Rural (99%) Urban Residential (1%)
C2	7517.0	2.1	5	Rural
C3	2595.5	1.9	5	Rural
C4	3637.1	1.6	40	Rural (48%) Urban Residential (42%) Commercial (10%)
C5	964.8	2.9	5	Rural (83%) Forest (17%)
C6	437.9	2.4	5	Rural
C7	2057.3	2.2	5	Forest (56%) Rural (44%)
C8	857.1	4.8	5	Rural
C9	752.2	4.9	5	Forest (73%) Rural (27%)
C10	3814.3	1.9	5	Forest (68%) Rural (32%)
C11	76.7	9.9	5	Forest (75%) Rural (25%)
C12	1032.3	4.1	5	Forest (90%) Rural (10%)
C13	122.4	4.8	5	Rural
C14	1720.5	3.6	5	Forest (52%) Rural (48%)
C15	785.4	5.4	5	Forest
C16	71.5	8.2	5	Forest
C17	34.2	9.7	5	Forest
C17a	23.5	13.3	5	Forest
C18	36.2	5.3	5	Rural
C19	105.6	8.4	5	Rural
C20	426.5	4.6	5	Rural
Total Area	**34,480**			

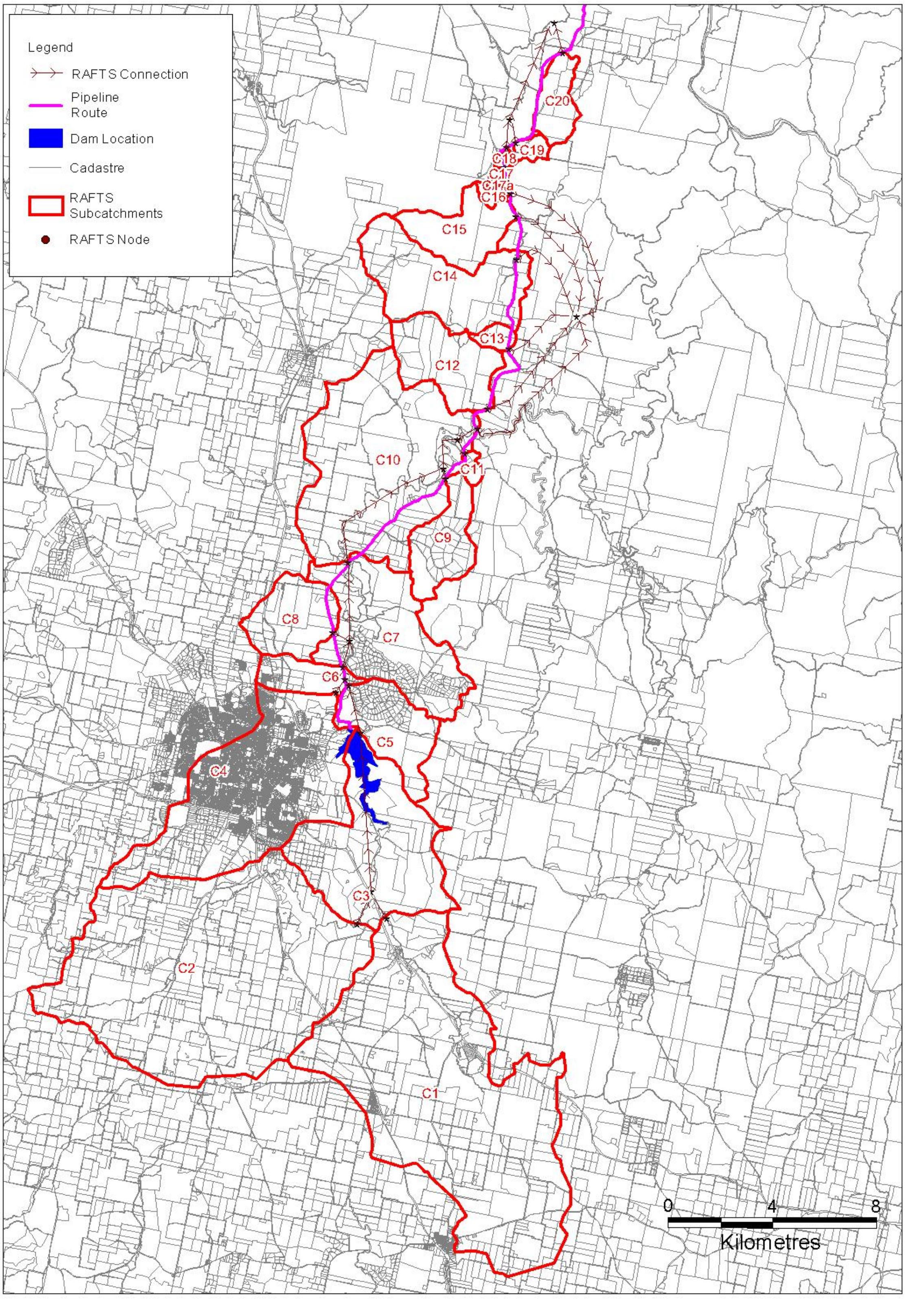


Figure 4-1. Sub-Catchments for Pipeline Route

4.2 Catchment and Crossing Descriptions

A general description of each of the catchments is provided in **Table 4-2**, along with the associated stream or crossing ID that was adopted for the geomorphology assessment.

Site inspections were undertaken as a part of the geomorphological assessment on a number of the crossings along the pipeline route. Crossings were selected for inspection based on the contributing upstream catchment. For crossings where the catchment was small, a site inspection was not undertaken. These are noted with a "NB" below. Where there was no crossing across the pipeline route (i.e. an upstream catchment), a "NC" is noted below.

Table 4-2. Catchment and Crossing Description

Catchment ID (RAFTS)	Crossing/ Stream ID	Description
C1	NC	Captures the beginning of Summer Hill Creek, and all the minor tributaries that drain onto it.
C2	NC	Consists of Brandy and Spring Creek which drain on to Summer Hill Creek
C3	NC	C1 (Summer Hill) drain on to this catchment as does C2 through Gosling Creek which finally falls onto Summer Hill. Suma Park Reservoir is located within C3
C4	NC	Summer Hill Creek does not go through C4 however, Blackmans Swamp Creek which is a primary tributary of Summer Hill and East Orange Creek which is a secondary Tributary of Summer Hill flow through C4
C5	1	Contains Summer Hill Creek and its minor tributaries
C6	2	Contains Summer Hill Creek and its minor tributaries
C7	4	Contains Summer Hill Creek and its minor tributaries
C8	3	Consists of minor tributaries that contribute to Summer Hill Creek
C9	21	Contains Broken Shaft Gully (secondary, Summer Hill) and Cow Creek (primary, Summer Hill) that eventually drain on to Summer Hill.
C10	5	Summer Hill Creek crosses through this catchment as does Mullion Creek (primary, Summer Hill)
C11	NB	Eldorado Gully passes through that drains onto Summer Hill Creek
C12	6	Kitty's Creek and Diggers Creek that drain onto Summer Hill
C13	7	Minor tributaries of Summer Hill
C14	25 &12	Oaky Creek passes through and finally drains on to Summer Hill
C15	14	Minor tributaries of Summer Hill Creek
C16	NB	Tributaries of Oaky Creek
C17a/17b	NB	Tributaries of Oaky Creek
C18	NB	Tributaries of Oaky Creek
C19	NB	Contain Cartys Creek which drains on to Boshes Creek
C20	30	Tributaries of Boshes Creek

4.3 Suma Park Reservoir

Suma Park Reservoir is a key feature of the study area. The stage-discharge relationship for this reservoir was obtained using the available terrain data. At the time of the hydrological analysis, only contour information was available, and bathymetry data had not been provided. In the absence of any available information on the spillway, the outlet was assumed to be a 65m wide weir with an elevation of 844 m AHD. Conservatively it has been assumed that the dam is full before the storm events begin, with an initial water level of 844 m AHD.

4.4 Hydrological Model Parameters

A number of parameters are required in the development of the RAFTS model, including initial and continuing rainfall loss rate, and catchment roughness.

Catchment roughness values were generally set at 0.045 and 0.08 for rural and forest areas respectively. For the catchment which was inclusive of Orange, a value of 0.015 was adopted for the impervious portion of the catchment.

The initial and continuing rainfall lost rates for impervious/pervious areas are presented in **Table 4.3**. The initial loss rates for the pervious areas are likely to be on the conservative side for this catchment. A weighted value of these was assumed for the catchment inclusive of the urban area of Orange.

Table 4-3. Rainfall Loss Rate

Rainfall Loss Rate	Impervious Area	Pervious Area
Initial loss (mm)	1.5	10
Continuing loss (mm/hr)	0	2.5

4.5 RAFTS Connections

The velocities for the hydrograph routing lags were defined for the individual channels, using the method described by Hee (1993). These were then combined with the estimated distances of the routing lags to determine an approximate routing time.

4.6 Design Rainfall

The study is focused on a number of creek crossings which are either connected as part of the Summer Hill Creek catchment, or separate tributaries. Given this focus on the crossings, a uniform rainfall distribution was assumed for the study area. The design Intensity-Frequency-Duration (IFD) parameters were obtained from the Bureau of Meteorology. The IFD parameters are shown in **Table 4.4.** The design rainfall temporal patterns were developed using standard techniques provided in Australian Rainfall and Runoff (AR&R) (Engineers Australia, 1999). **Table 4.5** lists the rainfall intensities for a full range of design events.

Table 4.4. Design IFD Parameters

Parameter	Value
2-Years ARI 1-hour Intensity	24.96 mm/hr
2-Years ARI 12-hours Intensity	4.48 mm/hr
2-Years ARI 72-hours Intensity	1.2 mm/hr
50-Years ARI 1-hours Intensity	49.85 mm/hr
50-Years ARI 12-hours Intensity	7.61 mm/hr
50-Years ARI 72-hours Intensity	2.07 mm/hr
Skew	0.26
F2	4.32
F50	15.59
Temporal Pattern Zone	2

Table 4.5. Design Rainfall Intensities (mm/hr)*

Duration	Return Period (Years)						
hr min	1	2	5	10	20	50	100
0 10	39.6	52	69	80	94	115	131
0 30	27.8	36.4	48.1	56	66	79	90
1 00	18.8	24.5	32.2	37.1	43.6	53	60
1 30	14.4	18.7	24.3	27.8	32.6	39.1	44.3
2 00	11.8	15.3	19.8	22.6	26.4	31.5	35.7
3 00	8.96	11.6	14.8	16.8	19.5	23.2	26.1
6 00	5.57	7.14	8.97	10.1	11.6	13.7	15.3
9 00	4.22	5.39	6.7	7.5	8.6	10.1	11.2
18 00	3.46	4.42	5.45	6.08	6.95	8.11	9.03
24 00	2.62	3.34	4.12	4.59	5.25	6.13	6.81

[+] Values derived from AR&R IFD calculations

4.7 Model Results

The RAFTS model results at reference points, whose locations are shown in **Figure 4.1**, are summarised in **Table 4.6**.

Table 4-6 XP-RAFTS Model Results

Nodes	2 Year ARI		5 Year ARI		20 Year ARI		100 Year ARI	
	Peak Flow (m^3/s)	Critical Duration (hr)	Peak Flow (m^3/s)	Critical Duration (hr)	Peak Flow (m^3/s)	Critical Duration (hr)	Peak Flow (m^3/s)	Critical Duration (hr)
C1	35	9h	59	9h	101	6h	164	6h
C2	59	6h	100	6h	162	6h	262	3h
C3	110	6h	186	6h	302	6h	473	3h
C4	110	2h	189	3h	323	1h	538	1h
C5	69	6h	121	6h	207	6h	343	6h
C6	126	2h	216	3h	369	1h	616	1h
C7	157	2h	274	3h	449	1h	758	1h
C8	17	6h	28	3h	47	2h	78	1h
C9	12	6h	19	6h	32	3h	52	2h
C10	181	6h	315	3h	516	3h	829	1h
C11	2	2h	4	3h	6	1h	11	1h
C12	12	6h	20	6h	32	3h	53	2h
C13	4	2h	6	3h	10	1h	18	1h
C14	18	6h	30	6h	48	3h	78	2h
C15	11	6h	18	6h	29	3h	48	2h
C16	2	2h	3	3h	6	1h	9	1h
C17	1	2h	2	3h	3	1h	6	1h
C17a	2	1h	4	1h	6	1h	10	1h
C18	1	1h	2	1h	4	1h	7	1h
C20	9	3h	16	3h	26	2h	45	1h

4.8 Hydrological Model Validation

Since no flow gauging data was available to calibrate the model, the hydrological model was validated by comparing the XP-Rafts results with that of the Rational Method.

In order to validate the hydrological model, the Rational Method was used to estimate the peak flows for sub-catchment C13 for a number of design events. The detailed procedures of the Rational Method are defined in Australian Rainfall and Runoff (AR&R) (Pilgrim (ed), 1999). The validation results are presented in **Table 4.7**.

Table 4.7 Results for Sub-catchment C13 based on RAFTS model and Rational Method (Peak Flow, m^3/s)

Storm (ARI)	Rational Method	RAFTS	Difference (%)
100 Year	13.0	18	38
20 Year	8.8	10	13.6
5 Year	6.0	6	0

The RAFTS model generated higher peak flows than those based on the Rational Method with the exception of the 5 year ARI. For 100 year ARI event, the peak flow at the outlet based on the RAFTS model is approximately 38% higher than one calculated by the Rational Method. Given the uncertainties associated with the Rational Method, this is considered reasonable.

4.9 Discussion & Conclusions

The hydrological modelling discussed above has defined the peak flows for the 2 year ARI, 5 year ARI, 20 year ARI & 100 year ARI design events for a number of the creek crossings along the pipeline.

This information can subsequently be utilised to assist with the design process for the pipeline. It is understood that the pipeline is proposed to be either trenched or tunnelled under each of the crossings. As such, there should be a limited impact on the hydrology in the study area because the proposed works do not alter the cross section of the creek.

A flood impact assessment would be undertaken to ensure no adverse impacts in the events up to the 100 year ARI event.

Similarly, any above ground infrastructure should be located above the 100 year ARI event to minimise impacts of flood behaviour.

If an alternative above ground option is adopted for the pipe, then a flood impact assessment will need to be undertaken. Furthermore, the expected loadings on the pipe from flood flows and debris would need to be determined.

To minimise potential damage to pumping infrastructure, pumps would be placed above the 1% AEP flood level plus a freeboard of 500mm. The 1% AEP flood level estimated by the HEC RAS model of Geolyse was 373.3m AHD.

5 GEOMORPHOLOGY

The 37km long proposed pipeline crosses a number of streams and it is a requirement of the DGRs to assess the impact of construction and operation of the pipeline to stream geomorphology. This stream stability assessment is limited to the relationship of the construction and operation of the pipeline and the potential for surface water to degrade streams at the crossings. The construction of the pipeline is expected to represent the greatest level of impact to stream stability and geomorphology.

In the absence of further details on the design, it has been assumed that the pipeline would be trenched for the crossings, being the construction method bearing the highest level of impact. Intrusive construction methods with heavy machinery would therefore be required to trench the pipeline in the rock dominated streams. Operation of the pipeline is not predicted to pose hazards to stream stability considering the pipeline is to be buried within a trench.

5.1 Stream Description

5.1.1 Topography

Ground contours of the region suggest that the area can be described as undulating hills with steep confined valleys. Some variation occurs along Summer Hill Creek where topography flattens into broad pockets of floodplain with a wide and shallow inset channel. The Macquarie River is a deep ravine in the location of the offtake with bank slopes of approximately 40% and the Boshes Creek confluence immediately downstream.

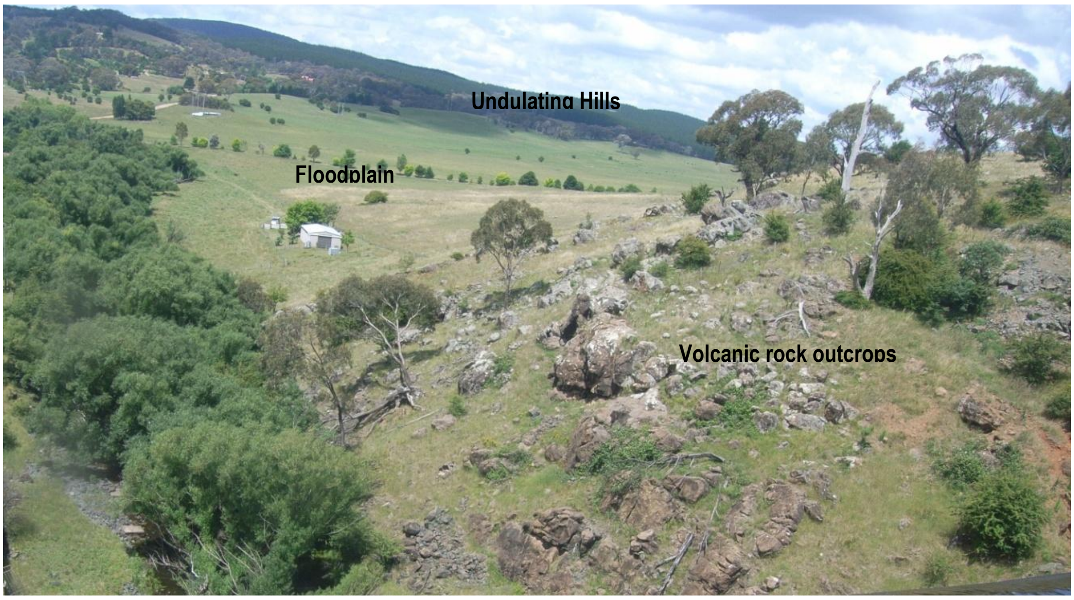


Figure 5-1: Topography of Orange: Undulating hills with floodplain pockets

5.1.2 Geology

In general the geology of the land along the pipeline route is volcanic bedrock with overlying silt/clay soil. Floodplain pockets exist particularly along Summer Hill Creek and comprise fine particle clay/silts. At the off-take location the river and Boshes Creek have exposed Slate, Basalt and Rhyolite on the riverbanks and bed with deposits of weathered rock.

5.1.3 Vegetation

In general trees and shrubs are sparse along the creek crossings. Grasses, both natural and exotic, are predominant along the creek banks and floodplain pockets. Small Eucalypts, Casuarina and Willow trees are scattered along the stream banks. A continuous canopy was not observed at any of the stream crossings included in this assessment. Weed species of blackberry, tiger pear, privot and kikuyu were observed at most locations.

5.1.4 Stream Stability

It was observed that the streams are generally very stable being controlled by bedrock and rock outcrops in confined valley walls. However the stability of the creek bed and banks can be variable depending on the presence of overlying soil, in-stream alluvial deposits and pockets of floodplain. Erosion of the floodplain was most obvious for Summer Hill Creek where the change in hydrology, due to the upstream reservoir, has caused incision and bank scour. However the scour appeared to have occurred in years past and the creek and floodplain has since stabilised.

Figure 5-2: Summer Hill Creek

Oaky Creek appeared to be the most unstable of the stream crossings observed. Reworking of the creek banks is in process on both sides of the channel. Creek banks comprise clayey silt soil with eroded vertical banks. This has most likely been the result of cattle access and/or road works to the approaches and causeway causing the waterway to adjust in response. The creek bed comprises weathered rock and cobbles indicating that the bed is stable unlike the surrounding creek banks.

Figure 5-3: Oaky Creek looking downstream

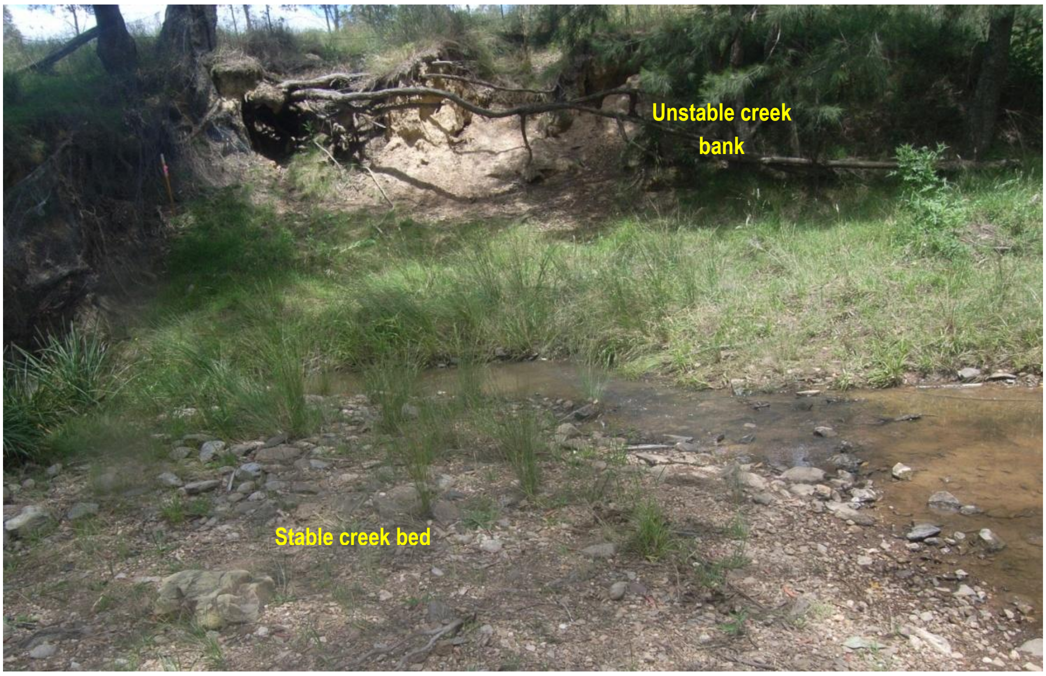


Figure 5-4: Oaky Creek – active erosion on right bank downstream of causeway

Macquarie River and Boshes Creek are very stable due to the abundance of high strength volcanic rock on the river bed, banks and valley walls.

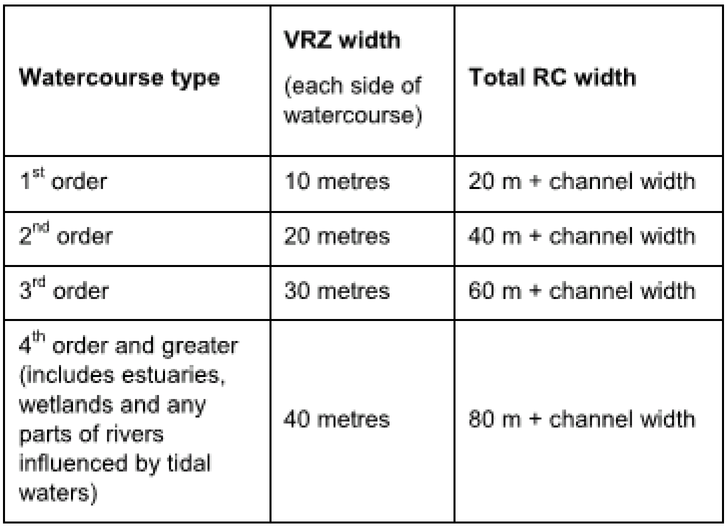
5.2 Geomorphology Assessment

5.2.1 General Approach

Generally the method of installing the pipeline would be by trenching as the provision of the NSW Office of Water Guidelines for trenching across watercourses is observed. An extract from the guidelines is provided below:

> *Proposals for trenching should*:
>
> - *prepare rehabilitation plans for disturbed bed and banks*
> - *locate or lay pipes or cables across the watercourse on the downstream side of channel bedrock outcrops and through the drop deposit zone if a plunge pool is present*
> - *avoid outside bends. Choose a straight section of the watercourse to cross*
> - *place infrastructure below calculated bankfull flow scour depths and allow a safety margin*
> - *avoid concrete caps and casings at shallow depths which may become exposed by bed lowering*
> - *ensure backfilling restores the channel shape and bed level to preconstruction condition*
> - *ensure a trench is open for the minimal length of time*
> - *avoid stopping the flow of a permanent watercourse by staging the trench across the channel or minimise the time involved in stopping or intercepting flows*
> - *address additional disturbances from temporary coffer dams or diversion of flows around work site, vehicle or machinery access and crossings and material stockpiles*
> - *prevent potential water quality issues such as turbidity or spills*
> - *address the recovery and* removal of construction plant and materials.

The above guidelines apply to the full riparian corridor width that applies to the respective stream order as outline by the NOW Guideline for Riparian Corridors on Waterfront Land, the corridor widths are as shown below:



Watercourse type	**VRZ width** (each side of watercourse)	**Total RC width**
1st order	10 metres	20 m + channel width
2nd order	20 metres	40 m + channel width
3rd order	30 metres	60 m + channel width
4th order and greater (includes estuaries, wetlands and any parts of rivers influenced by tidal waters)	40 metres	80 m + channel width

The pipeline will cross a number of waterways along its route. Desktop investigations identified over 30 crossings based on catchment delineation. The 30 crossings were then filtered to a number of key crossings for further assessment depending on the size of the catchment, presence of dry weather flow and permanence of a stream channel. The method of stream identification for further assessment may be related to second and third order streams of the Strahler method as defined in **Table 5.1.** These streams can be described as having either permanent or intermittent flows within a defined channel.

Table 5-1: Stream order description & requirements, as per Strahler method (Strahler 1957)

Stream Order	Description	Field Assessment Required
First	Any first order watercourse or where there is a defined channel where water flows intermittently	No
Second	Any permanently flowing first order watercourse, or Any second order watercourse, and Where there is a defined channel where water flows intermittently or permanently	Yes
Third	Any third order watercourse or greater watercourse and where there is a defined channel where water flows intermittently or permanently. Includes estuaries, wetlands and any parts of rivers influenced by tidal waters.	Yes

First order streams described as having drainage depressions, gullies and no defined channel were excluded from the field assessment as they are less significant in geomorphology terms. First order streams are predominantly short tributaries having little variation in stream character and are allocated smaller riparian buffer widths as a result (RCMS 2004). Trenching of the pipeline across first order streams should be conducted according the NSW Office of Water Guidelines, more specific trenching design and control is provided for other streams in this assessment.

5.2.2 Stream Crossings Assessed

Inspection of the stream crossing was undertaken in December 2011 using a stream stability assessment proforma, camera and GPS. The data recorded in the proforma is included in **Appendix E** and a summary of the data is included in **Table 5.2.** The stability of the creeks assessed was determined according to the material comprising the stream bed and banks and is described in **Table 5.3.**

Table 5-2: Stream stability assessment approach

Stability	Bed/Bank Material	Active Erosion	Riparian Vegetation
Very Stable	Bedrock & boulders	No	N/A – stream controlled by the presence of rock
Stable	Bedrock & boulders & gravel	No	Sparse - Good
Sensitive	Soil & gravel	No, evidence of previous erosion observed. Subject to erosion if channel surface is disturbed.	Sparse - Good
Unstable	Soil & clay & silt	Yes	Sparse - Fair

Vegetation Key:

Good - 100% cover of upper bank surface with grasses & sparse trees

Fair – 80-100% cover of surface with grasses & sparse trees

Sparse - 50-80% cover of surface with grasses plus sparse trees

Table 5-3: Stream crossing details

Crossing #	Chainage (m)	Name	Catchment (ha)	Bed Slope (%)	Bed/Bank Material	Stability	*Strahler Stream Order	Observations
1	34,800	Summer Hill Creek	18,489	0.67	Silt, Clay	Sensitive	3	Large expanse of floodplain on both sides of channel. Willows and poplar growing in-stream with evidence of previous removal. Permanent dry weather flows from suma.
2	34,000	Summer Hill Creek	22,564	0.25	Silt, Clay	Sensitive	3	Low siunousity channel with permanent flows and exotic vegetation growing in-stream and on channel banks. Large expanse of floodplain on both sides
3	32,630	-	800	0.85	Silt, Clay	Sensitive	2	Small inset channel in an expansive floodplain. Exotic vegetation growing in-stream and on channel banks
4	29,600	Summer Hill Creek	25,478	0.18	Silt, Clay	Stable	3	Sinuous channel abuts valley wall on right bank and expansive floodplain on left. Exposed bedrock on valley wall.

Crossing #	Chainage (m)	Name	Catchment (ha)	Bed Slope (%)	Bed/Bank Material	Stability	*Strahler Stream Order	Observations
19	27,085	-	163	4.97	Gravel, Silt, Clay	Sensitive	1	Irregular channel shape and evidence of previous erosion. Well vegetated with native shrubs and trees.
21	24,500	Cow Creek	753	2.75	Cobble, Gravel, Silt, Clay	Sensitive	2	Small inset channel in valley floor with controlled planform. Mobile channel bed of gravel/sand.
5	21,870	Summer Hill Creek	30,121	1.38	Silt, Clay	Sensitive	3	Sinuous channel controlled by bedrock and confined valley. Sediment deposits downstream of road crossing.
6	20,730	Kittys Creek	1,032	1.60	Bedrock, Gravel, Silt, Clay	Stable	2	Lowering of creek bed indicated by head-cut upstream. Pipeline to be located downstream where stability is higher.
7	17,550	-	90	2.75	Boulder, Cobbles, Silt, Clay	Stable	1	Irregular channel inset in rolling plains. Previous erosion observed, now stable.
12	13,850	Oaky Creek	1,680	0.67	Bedrock, Gravel	Unstable/ Sensitive	2	Sinuous channel with meanders adjacent to valley walls. Stream bed stable comprising cobbles/sand, bank instability observed on outside bends. Stable in straight reaches.
25	13,500	Oaky Creek	1,720	1.00	Bedrock, Boulder, Cobbles, Silt, Clay	Sensitive	2	Stream banks of higher stability in this location. Good cover of trees and numerous shrubs.
14	12,126	-	786	0.55	Boulder, Cobble, Silt, Clay	Very Stable	1	Straight channel filled with cobbles and gravel. Appears to have been constructed.
30	4,358	-	427	2.14	Boulder, Cobble, Silt, Clay	Very Stable	2	Planform controlled channel with bedrock exposed in-stream and on valley walls.
Off-take	0	Macquarie River	-	0.30	Bedrock	Very Stable	>3	See Section

**Stream orders greater than 3 are all reported as 3 as they are generally representative of major perennial streams and have the same requirements for riparian corridor widths for category 3 streams*

The collection of the data from the site inspections found that the streams are stable for the most part because only one of the stream crossings assessed was found to be unstable. The stability found was commonly due to the presence of highly resistant channel materials and/or good vegetation cover. Streams that are noted as unstable require rehabilitation following construction of the pipeline in order to maintain stream geomorphology. Streams noted as sensitive displayed some evidence of erosion that had occurred in the past. This was most likely a result of land clearing, rural land use and the construction of the road crossing. These changes were expected to occur well before the time of inspection and as such the current stability is only sensitive to erosion should disturbance in-stream take place. The in-stream disturbance is proposed by the trenching of the pipeline. Discussion of mitigation impacts for the sensitive and unstable stream categories is included in **Section 5.3**.

5.2.3 Macquarie River Off-take

Geomorphology

The proposed location of the pipeline off-take is on the left bank of the Macquarie River where there is a natural pool situated directly upstream of the Boshes Creek confluence. The pool is known as Gardiners Hole and river bed survey suggests the hole is up to 3m deep adjacent to the left bank. Dry weather flows fill the hole from both the river and the creek as they are detained by a rock riffle situated directly downstream of the confluence. The river channel is approximately 60m wide at Gardiners Hole and is constricted by approximately 80% at the riffle crest. As such the dry weather flow velocity is very low in Gardiners Hole considering the retarding qualities of the deep pool and constriction.

The valley setting of both the river and the creek is confined and very steep with an average bank slope of 30-40%. The riverbank is controlled by exposed bedrock up to 1m above the water level recorded during the site inspection and in the river bed survey. The valley walls above the exposed bedrock comprise a thin layer of topsoil supporting sparse trees, shrubs and a good cover of grasses. Volcanic rock outcrops are scattered amongst the vegetation.

River flows were turbid with entrained particles and alluvial deposits were observed on the dry parts of riverbank and riffle. Weathered rock exists over most of the riffle with alluvial deposits trapped in the rock voids that are supporting vegetation. This suggests that the entrained particles in the river are deposited in this location due to the roughness of the rock riffle and the constriction working in conjunction to retard flows to a level where the sediments can settle.

Figure 5-5: Proposed offtake location on left bank looking downstream

Figure 5-6: Looking upstream from the riffle at the Boshes Creek Confluence

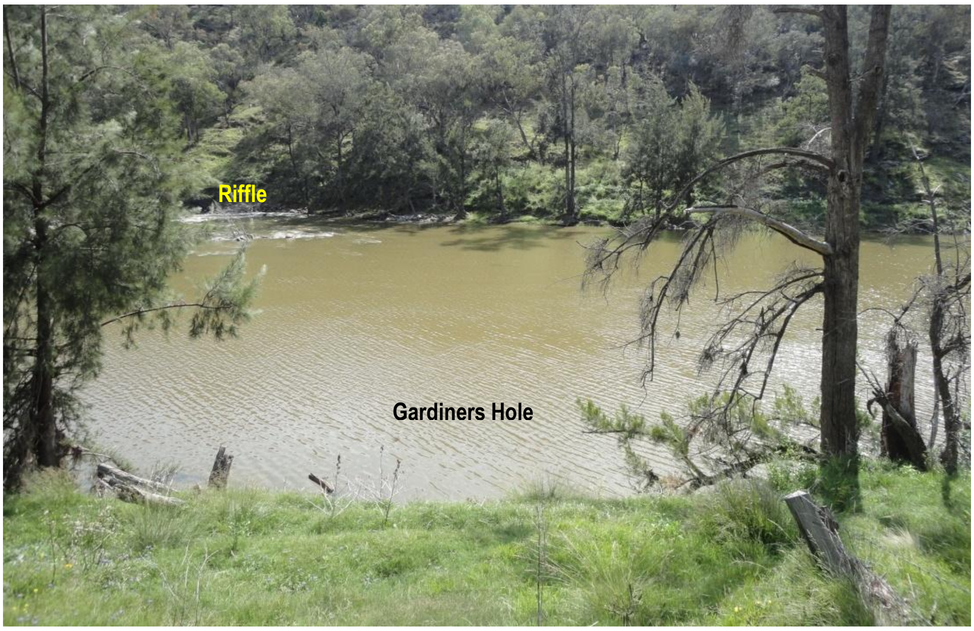


Figure 5-7: Looking downstream from the upper left bank

River Stability

The river bank and bed materials are high strength rock being resilient to hydrodynamic forces from the river. No reworking of the riverbank would be expected beyond erosion of the thin layer of topsoil during regular storms. Reworking of the riverbank and bed would not be expected beyond the exposed bedrock. Alluvial material will naturally be eroded during high flows and replenished between storm cycles as sediment is deposited from the stream bed load. In addition erosion of the topsoil and alluvial material is expected to be reduced by the retardation of flows by the constriction and the pool of Gardiners Hole. As a result of these physical qualities the river stability is high.

A preliminary hydraulic model (HEC RAS) was made available by Geolyse for Gardiners Hole using river survey undertaken in October 2011. The model is considered suitable for estimation of river hydraulics at the preliminary stages of the design. The model reach begins from the spill crest of the riffle and continues 260m upstream. Input flows to the model were also provided for the 50%, 5%, 1% and 0.5% AEP.

The model was run to predict velocity and shear stress in the river channel and on the upper left bank above a raised level of 365.5m AHD, being the water level at the time of survey when the flow was estimated to be 2000 ML/day. Results of the model in Table 5.4 show that the flow velocity and shear stress on the upper left bank is negligible as a good cover of grass can resist flow velocity of 2m/s for durations of up to 50 hours (CIRIA 1985). Flow velocity and applied shear force in the channel is sufficient enough to entrain particles up to a diameter of 100mm (Knighton 1998). Note that these findings are subject to update following more detailed hydraulic investigations and detailed design.

Table 5-4: HEC RAS model results

AEP	Flow (m^3/s)	Flood Level (m AHD)	Depth Above Offtake (m)	Shear Stress Left Bank (N/m^2)	Shear Stress Channel (N/m^2)	Velocity Left Bank (m/s)	Velocity Channel (m/s)
50%	201	367	1.5	1.98	8.36	0.2	0.9
5%	1,829	370.8	5.3	42.53	121.16	1.1	3.87
1%	3,632	373.11	7.61	85.1	242.77	1.83	5.74
0.2%	5,809	375.07	9.57	138.59	387.46	2.38	7.49

Proposed Off-take

At the time of reporting configuration of the Macquarie River off-take has been proposed MWH according to the sketches included in Appendix A. Given that the design is in preliminary form, the level of impact assessment and nomination of mitigation is of a similar level. In general the off-take is expected to include an offtake structure situated at the riverbank toe that would collect flows into a sump that has a manifold connection to a 15m deep pump well. A vertical shaft pump is to be located in the well to lift water to the level of the pipeline approximately 1-2m below natural surface. The location of the pump well is approximately 15m up the river bank at the approximated level of the 100 year ARI. It has been advised to Council by Geotechnical Consultants that a rock hammer could effectively break the in-situ rock for the offtake and manifold. Therefore the structures predicted within the fluvial influence of the river would be a buried manifold and offtake structure. Minimal width of excavation would be required to support the proposed structures considering that the foundations are of high strength rock.

Appendix A includes a typical section of the offtake configuration. A concrete pit is to be embedded into the toe of the riverbank so that there are minimal protrusions into the fluvial zone of the river. Flows are to be accepted into a grated opening that is roughly in line with the contours of the existing bedrock. As such there is limited opportunity for the offtake to introduce hydraulic change and therefore negligibly impact to the riverbank would be expected by fluvial processes.

Disturbance to the river bed and bank would be defined by the footprint of the off-take structure and the manifold trench. Intrusive disturbance would be of little concern to the stability of the river up and downstream due to the high strength of the river bed and bank materials and the hydrodynamic forces estimated by the HEC RAS model (Geolyse 2012). Therefore the impact of the proposed off-take to fluvial processes would be limited to minor increases in turbulence in the vicinity of the structure. The turbulence would not have the potential to scour surrounding bedrock, however there is the potential for some minor scour to the disturbed surfaces following construction. In order to protect the riverbank from scour the application of igneous rock rip rap is recommended. The following calculations were made using the Pilarzcyck method (M&C 2000) and based on the flows that were provided with the HEC-RAS model. It should be noted that these are preliminary calculations reflective to the level of detail in the data provided. More hydraulic modelling and calculations are recommended once the design progresses to a more detailed level.

Macquarie River

Case		50% AEP	5% AEP	1% AEP	0.2% AEP
Riprap stone diameter [m]	**d_{50}**	**0.00**	**0.12**		**-**
Riprap stone mass [kg]	d_{50} m	0.00	2.58	81.02	82.0
Flow depth [m]	y	*1.5*	*5.3*	*7.6*	*9.6*
Velocity adjacent to bank [m/s]	V	*0.2*	*1.1*	*1.8*	*2.4*
Stability factor	$\Box_c$	*1.50*	*1.50*	*1.50*	*1.00*
Turbulence factor	K_t	*2.0*	*2.0*	*2.0*	*2.0*
Specific gravity of stone	S_s	*2.60*	*2.60*	*2.60*	*2.60*
Bank slope angle [degrees]	□	*30*	*30*	*30*	*30*
Rip rap repose angle [degrees]	□	*36*	*36*	*36*	*36*

Notes:

- User input defined by text in *italics*
- Velocity on the left bank is lower than in the centre of the channel due to a change in roughness allocated to the location of the offtake. Roughness for the channel is n=0.04 and roughness for the bank is n = 0.07.
- Turbulence and stability factors were added to suit a structure with exposed edges that protrudes into the flowpath of the riverbank.
- Rock specific density of 2.6 is representative of volcanic rock such as basalt or locally available equivalent

The estimated rock sizes in the calculations are for placement of rock at the locations shown in Appendix A. Rock sizing for the depths and velocities indicates that an average diameter 400mm is suitable according to the above calculations for the 1% AEP. This rock size has a critical shear stress threshold of approximately 150 N/m^2 and would resist the shear stress estimated at the left bank (~140 N/m^2) in the 0.2% AEP (Knighton 1998). It is therefore recommended that a median value of 400mm would be a suitable rock size for scour protection given that it is in the range of the sizes estimated by the Pilarzcyck method and would be stable for less frequent storm events should they occur.

The rip rap should be laid in a minimum thickness of 600mm (average rock size x 1.5) and lined with a heavy duty, non-woven synthetic geotextile. Rock material is to have a minimum specific gravity of 2.6 and an angle of repose greater than 36 degrees. Therefore the rock should be of volcanic origin and very angular in shape and laid at bank angle of no more than 30 degrees.

The above calculations are based on the discharges as supplied with the HEC-RAS model in its preliminary form. These results should therefore be considered indicative. The results should be revised once more detailed information is available on difference discharges and the level of protection in regards to recurrence interval that is required for the off-take.

5.2.4 Suma Reservoir Discharge

The reservoir was inspected and at the time the water was ovetopping the spillway. A full appreciation of the reservoir banks was not achieved due to the high water level. A photograph of the suggested discharge location is shown in **Figure 5.8**. This location would be suitable for the discharge as the existing banks have a shallow grade and rock lining exists at the TWL. Minimal disturbance would be required to construct the discharge and rock lined channel in this location. The water will flow out of the discharge structure and flow via a rock lined channel located down the inside of the dam embankment and into the water. The top of the discharge structure will be approximately 3.0m above the Tail Water Level (TWL). A maximum grade 1 vertical to 6 horizontal should be applied to the rock lined channel so that it is approximately 20m in length from the discharge point to the TWL. Suitably sized rock rip rap should be laid on the rock lined channel to resist erosion and to control scour at the interface with the TWL.

Figure 5-8: Suggested location of pipeline discharge to the reservoir

5.3 Sediment & Erosion Control

The pipeline is to be trenched across the waterways. The geology of the pipeline route is such that medium to high strength rock exists either at, or at some depth below, natural surfaces. Overburden of alluvial soil and/or clays are also common and are most likely at the crossing nominated as Unstable or Sensitive. It has been advised by geotechnical consultants that an excavator would undertake the trenching with a bucket in soil or a rock breaker in med-high strength rock. Therefore a strip of disturbance is to be expected within the waterway at each of the crossings. **Table 5.5** summarises the stability of the waterways, which to a large extent describes the likely impacts that would occur as a result of the trenching.

Unstable waterways and those that are Sensitive would likely incur superficial disturbance during construction and a risk of erosion thereafter. An overburden of silty clay is most common in these waterways and mitigation of the disturbance following construction would both rehabilitate the trench footprint and reduce the risk of erosion. A suitable method of mitigation is included in Detail 7 on drawing W4916 – 2A where the backfilling of the trench is topped with graded rip rap of local origin and topped with local soil. Fully structured vegetation should be planted of local provenance species would follow the application of topsoil. Coir matting is proposed over the full footprint to reinforce the soil until the riparian vegetation becomes established.

Stable waterways comprise of rock bed and banks. The trench would be broken through the rock to a shallow depth to allow for encasement of the pipeline in concrete. It is proposed that local rock spalls are cast into the surface of the trench to mitigate impacts to stream and fluvial geomorphology.

Potential erosion and sediment control measures have been developed for each of the creek crossings identified in the geomorphology assessment. These have been included to provide protection to the creeks during the construction period. These measures are detailed in with associated example drawings located in **Appendix A**.

It is noted that the exact erosion and sediment control measures will be highly dependent on the final construction methods adopted. These should therefore be updated as the design is updated.

It is also noted that there are a number of additional smaller creeks and drainage paths along the pipeline route. While these are generally minor, ephemeral and have not been included in the geomorphology assessment, they will also require erosion and sediment control measures during the construction period. For these crossings, the hay bay filter option, as shown in **Appendix A**, may be suitable.

Table 5-5: Erosion and Sediment Control Stream crossing details

ID	CH (m)	Stability	Dry Weather Flow	Flow Control Measure	Erosion Control Measure	+Trench Detail #	Mitigation opportunities*
1	34,800	Sensitive	Yes	Diversion Wall	Gravel Filter	7	The creek is the receiving environment for Suma Reservoir overflow. The width of the channel and presence of dry weather flows makes it an ideal site for bridge hugging with supporting piers as bridge structure is inadequate.
2	34,000	Sensitive	Yes	Coffer Dam	Gravel Filter	7	Rehabilitate disturbed areas by planting local provenance species
3	32,630	Sensitive	Yes	Diversion Wall	Gravel Filter	7	The suggested approach for this crossing is underboring to reduce impacts to the stream. This should be undertaken according to NOW guidelines.
4	29,600	Stable	Yes	Diversion Wall	Gravel Filter	6	Rehabilitate disturbed areas by planting local provenance species
19	27,085	Sensitive	No	Diversion Wall	Gravel Filter	7	Previous erosion appears to have stabilised
21	24,500	Sensitive	Yes	Coffer Dam	Gravel Filter	7	Previous erosion appears to have stabilised
5	21,870	Sensitive	Yes	Diversion Wall	Gravel Filter	7	Rehabilitate disturbed areas by planting local provenance species
6	20,730	Stable	Yes	Coffer Dam	Gravel Filter	6	
7	17,550	Stable	No	None	Hay Bales	6	
12	13,850	Unstable	Yes	Diversion Wall	Gravel Filter	7	Oaky Creek Causeway - bridge hugging not an option. Crossing should be located away from the causeway that includes an S bend with instability on outside banks. Straighter sections of the creek present a more stable condition and would be more suitable for the trenching. Rehabilitate creek banks with compacted local soil at maximum 1 vert: 3 horiz. Plant disturbance zone with fully structured vegetation for the full width of the riparian corridor and cover with biodegradable Jute Mesh.
25	13,500	Sensitive	Yes	Diversion Wall	Gravel Filter	7	Not a crossing, pipeline hugs left bank of creek. Rehabilitate creek bank with compacted local soil at maximum grade of 1

ID	CH (m)	Stability	Dry Weather Flow	Flow Control Measure	Erosion Control Measure	+Trench Detail #	Mitigation opportunities*
							vert: 3 horiz. Plant disturbance zone with endemic species and cover with biodegradable Jute Mesh.
14	12,126	Very Stable	No	None	Gravel Filter	6	
30	4,358	Very Stable	No	Coffer Dam	Gravel Filter	6	
Off-take	0	Very Stable	Yes	Diversion Wall	Floating boom and sediment curtain	6	Difficult to control flows during construction for long periods - suggest increasing diversion wall height to 2m above water level in River ~ 367.5 m AHD. Further attention to suitable sediment and erosion control should be undertaken during detailed design.

**Mitigation measures are included to suggest possible methods to eliminate disturbance to the streams and avoid erosion. Particular attention has been made to streams that are either Unstable or Sensitive.*

+Trench Details included in Appendix A

6 SURFACE WATER QUALITY

6.1 Water Quality in Suma Park Reservoir

Cardno has undertaken a preliminary assessment of water quality data for the Macquarie River that was provided by GHD on 21 September 2011 (**Section 3.1**). The key focus of this assessment is on the relationship between the various measured river water quality parameters and available river flow data, to consider the potential impact of transferring water from the river to the Suma Park Reservoir and the consequent potential effects on the Icely Treatment Plant.

The potential impact of the various water quality parameters on the Reservoir has been assessed through two main methods:

- Pollutant mass balance modelling – an analysis was undertaken over an approximate 120 year period and assuming perfect mixing within the reservoir. This is further detailed in **Section 6.1.4**
- 3D Reservoir Modelling – this modelling provides a more refined analysis of the mixing of the different input flows into the reservoir and the likely proportion of the reservoir water would be represented by Macquarie River inflows at different points within the reservoir. Further details of this are provided in **Section 6.1.5**

6.1.1 Selection of Water Quality Parameters for Analysis

Water quality parameters were chosen for analysis based on a number of criteria:

- Where parameters exceeded ANZECC (2000) guidelines (for reservoirs) or where the median value in the River was above the Reservoir. Additional parameters were also selected, such as TN and TP, due to their influence on natural processes in the Reservoir.
- Parameters from the river were identified as exceeding the 95th percentile of the data set from the Suma Park Reservoir, and may therefore pose a risk during certain flow periods.
- Parameters represent potential key parameters for either the treatment process or the health of the reservoir.
- The River water quality parameters exceeded ANZECC (2000) guidelines for reservoirs.

6.1.2 Analysis of Selected Water Quality Parameters

The analysis of the various water quality parameters was undertaken by graphing the measured flows from the River against the measured concentrations. Additional information is provided on each graph showing the mean value and 95th percentile water quality value from the Reservoir, for comparison. This information is provided in a series of charts provided in **Appendix B.** Table 6-5 summarises the results of this analysis, indicating which parameters displayed a relationship with flow and the strength of this relationship. This is further discussed in **Section 6.1.3**.

6.1.3 Investigation of Relationships

One of the key methods for control of any potential water quality impact on the Reservoir is through flow and water quality trigger values. These trigger values will define when it is possible for pumping to occur from the River through to the Reservoir. The following bases for trigger values have been considered in this assessment, as these are all possible using real time systems:

- Flow-based trigger – based on a suitable gauge site upstream of the proposed offtake site in the River;
- Turbidity-based trigger;
- Conductivity-based trigger.

In general, the focus of this assessment has been on flow-based triggers for each of the parameters, however, turbidity-based and conductivity-based triggers have also been considered where the relationship of a particular water quality parameter with flow is weak. A table summarising the key relationships between each of the parameters based on the available data is provided in **Table 6.2.**

It is noted that the key limitation of this assessment is that all but one water quality sample has been collected for river flows greater than 100ML/ day. This makes identification of suitable low level triggers (e.g.at river flows of 30ML/ day or similar) difficult to reliably quantify.

Flow-based Triggers

The results of the assessment detailed in **Section 6.1.2** suggest that the concentrations of some water quality parameters increase with flow while other parameters decrease with flow. As a consequence, water quality parameters have been identified that may require a low level flow-based trigger limit or a high level flow-based trigger limit.

The following parameters may require a low level trigger limit:

- EC & TDS;
- Bromide
- Barium.

The following parameters may require a high level trigger limit:

- Aluminium
- Iron (Fe)
- Nitrogen (TN, TKN etc)
- TOC
- TP.

Turbidity-based Triggers

The following parameters may require a turbidity-based trigger:

- Nitrogen – potentially to be used in parallel with a flow-based trigger;
- Somatic Coliphage.

Water Parameters with no Relationships

The following parameters are not correlated with either flow, EC or turbidity. They have been identified as they may either impact on the reservoir or the treatment plant process. As a trigger cannot be set for these, they will potentially need to be managed either before entering the reservoir or through the treatment process. This will depend on the level of significance of each parameter on the Reservoir:

- Manganese;
- Clostidium Perfringens; and,
- BOD.

Note that there are a number of other parameters that were identified in **Appendix B**. However, as these parameters only have a single sample recording for the River, detailed conclusions cannot be drawn from these values.

6.1.4 Pollutant Mass Balance Modelling

A preliminary analysis of impacts on reservoir water quality was undertaken by pollutant mass balance modelling for each of the parameters identified in **Section 6.1.1 .** This is a simple analysis assuming conservative species and perfect mixing in the reservoir, to identify potentially problematic pollutants for the health of the reservoir. The analysis was undertaken comparing the existing scenario with a pumping scenario. The pumping scenario adopted incorporated a pump rate of 12 ML/day into the reservoir when storage drops below 90% and river flow is greater than 34 ML/day.

Pollutant concentrations were modelled at a daily time step spanning 1890-2007 using the results of reservoir water balance modelling carried out by Geolyse (see **Section 3.7**). A warm up period of 30 years was adopted to ensure no dependence on initial conditions. Pollutant concentrations in reservoir inflows (catchment runoff, stormwater harvest, river transfer) were treated as random variables distributed according to the empirical distribution function of the data. Where available, the relationship between river flow and concentration was used instead of random sampling. The mean over 30 realisations was taken as a measure of the expected or true concentration time series.

This analysis provides a preliminary review of the likely impact of the pumping on the reservoir water quality. It is important to note that this analysis provides a simplified representation of the reservoir:

- The analysis assumes perfect mixing in the reservoir. There may be localised higher concentrations in the vicinity of the discharge point, for example.

- Chemical or Biochemical processes within the reservoir which affect species concentration are not considered.
- Bacterial die off is not considered.
- Sample sizes for some species (particularly, Sodium, Chloride and Sulphate) are small which leads to bias in the concentration distribution.
- The impact of nutrient concentrations on algal growth has not been considered

Table 6.1 summarises the results of the analysis, providing an indication of possible changes to reservoir concentrations due to river transfers. For most species, the distribution of concentration does not change significantly with the inclusion of pumping, with the exception of Sodium, Chloride and Sulphate which increase (see **Appendix B**). This however can be attributed to the river water quality data containing only a single measurement that is considerably larger than concentrations in stormwater harvest water or catchment runoff.

The analysis indicates that the micro-organism levels in the reservoir tend to reduce when river transfers occur. This is expected, since micro-organism concentrations in the river are substantially lower than in catchment runoff, which forms the majority of inflows to the reservoir. Nutrient concentrations (Total Nitrogen, Total Phosphorous, Nitrate-N and Nitrate+Nitrite-N) do not change considerably. Total Nitrogen levels increase marginally, but this may be offset by the marginal decrease in Total Phosphorous.

The increases in Sodium, Chloride and Sulphate would suggest that salinity levels in the reservoir may increase with the pumping. However, as noted, there is only a single high measurement of each in the river which skews the results. A typical measure of salinity is through Electrical Conductivity (EC). EC has a high correlation with TDS. The relationship between TDS and Electrical Conductivity was therefore used to provide an indication of likely changes to salt concentrations in the reservoir. Based on the available water quality data for the river and the reservoir, it was found that TDS ≈ 0.6 x Electrical Conductivity. Using this relationship, changes to the distribution of Salinity are expected to be minimal (see **Table 6.1**).

Therefore, in summary, there are unlikely to be significant changes in the water quality within the reservoir overall. However, as noted, there may be localised changes in water quality in the vicinity of the discharge point from the pipeline. The level of this impact will be dependent on the level of mixing at the discharge point. 3D modelling is currently being undertaken to address the likely mixing of the pipeline input with the reservoir.

Table 6-1 Median concentration of pollutant species for the existing scenario and pumping scenario.

Parameter Name	Units	Median Concentration over time (no pumping)	Median Concentration over time (with pumping)	ANZECC trigger value (for freshwater lakes & reservoirs)
Nitrate-N	mg/L	0.03	0.04	NV
Nitrate+Nitrite-N	mg/L	0.02	0.03	NV
TN	mg/L	0.67	0.66	0.35
TP	mg/L	0.06	0.05	0.01
TDS	mg/L	211	213	NV
Electrical Conductivity†	µS/cm	351.7	355	20-30
SS	mg/L	9.50	10.26	NV
TOC	mg/L	9.24	8.84	NV
BOD	mg/L	3.02	3.15	NV
Al	mg/L	0.21	0.22	0.055*
Cu	mg/L	0.002	0.002	0.055*
Na	mg/L	12.25	17.23	NV
Ba	mg/L	0.04	0.04	NV
Fe	mg/L	0.71	0.70	NV
Mn	mg/L	0.31	0.28	NV
Cl	mg/L	10.73	15.94	NV
SO4	mg/L	5.23	9.61	NV
Total Alkalinity	mg/L	152	150	NV
Bromide	mg/L	0.07	0.07	NV
EColi	cfu/L	2747	2523	1260*
Somatic Coliphages	pfu/L	2041	1902	NV
Clostidium Perfringens	cfu/L	151	149	NV

**Note that these values have not been adjusted for hardness and alkalinity, as no hardness data is available. This may result in lower trigger values for these parameters.*
NV = No trigger value available in guidelines
†Note that median concentration for Electrical Conductivity has been determined using the relationship TDS = 0.6xEC.

6.1.5 3D Reservoir Modelling

3D modelling of the reservoir was undertaken in order to examine the impact of the thermo-hydrodynamic processes on reservoir water quality and the mixing of the various inputs to the Reservoir. One of the limitations with the mass balance modelling approach in **Section 6.1.4** is that it assumes perfect mixing of all inputs, whereas in reality there may be some areas within the Reservoir that may have higher concentrations of certain inflow inputs. Furthermore, given the proximity of the Discharge from the pipeline to the Reservoir Off-take, a potential was identified for 'short-circuiting' of flow from the Macquarie River to the treatment plant.

The following provides an overview of the modelling and results. Details on the model parameters and other aspects of the modelling are provided in Appendix F.

Model Setup

The Delft3D model was utilised for this because of its capability to describe the 3D current and density structures and to appropriately handle the following key processes which can impact on parameter concentrations within the reservoir:

- heat processes (solar radiation and water column penetration of heat);
- vertical mixing;
- meteorological variations;
- net evaporation/rainfall/seepage flows;
- wind forcing;
- influx/efflux caused currents.

These processes were modelled utilising the data outlined in **Table 6-2.** The model grid system was prepared with the main objective of having high resolution near the off-take, but it also needed to describe a large area in order to accurately represent the flow structure variations and heat storage and flux. Hence, a coarse grid with a grid size of 90m was linked to a finer grid of grid size 30m. This model system allowed a significant reduction of the duration of the simulations without reducing the resolution of the results and processes in the area of interest; that is, the dam off- take. For further details of the modelling methodology and results, see **Appendix F.**

Table 6-2 Data utilised for 3D Modelling of the Reservoir

Data	Source	Details
Lake Depth	Bathymetric data provided by Council	Bathymetry and survey data of the reservoir
Wind	Bureau of Meteorology	Hourly data at Orange Airport
Reservoir Flows	Geolyse	Water Balance Modelling (see Section 8.1.4)
Water Quality for Suma Park Reservoir	GHD	See Section 3.2
Macquarie River Water Quality	GHD	See Section 3.2
Solar Radiation	Bureau of Meteorology	Hourly data at Wagga Wagga
Relative Humidity	Bureau of Meteorology	Monthly data at Orange Airport
Air Temperature	Bureau of Meteorology	Monthly data at Orange Airport
Reservoir Temperature	GHD	Temperature Profile near the Reservoir Offtake (about 17m deep) taken between 2004 and 2011.

Model Calibration/ Verification

The model was calibrated to recorded on-site data, with verification undertaken by simulating a general period of one year. See **Section 4** in **Appendix F** for further details on model calibration.

Mixing Analysis within the Reservoir

The calibrated model was used to investigate the potential influence of contaminants in Macquarie River flows on water quality at the off-take. In these analyses three conservative marker contaminants were set at each of the three inflows – Stormwater Harvest, Suma Park catchment and the Macquarie River. This approach allowed the separate identification of the proportion of water originating from each source, at any point within the reservoir.

A period of two years from July 1996 to July 1998 was selected for analysis. During this period Macquarie River flows were relatively high with respect to the Suma Park catchment flows, and hence may represent a relative worse case scenario in terms of the proportion of Macquarie River inflows in the Reservoir. Results of the modelling are presented in **Figure 6-1**, showing 95 percentile levels of the Macquarie River tracer, which is representative of the proportion of the Macquarie River pumped water within the overall water body.

It is noted from these results that the embayment in the vicinity of the discharge point results in relatively high concentrations of Macquarie River pumped water, but this dissipates moving away from the discharge point, as would be expected. The analysis suggests that there is unlikely to be significant short-circuiting of flows from the Macquarie River discharge point to the Reservoir Off-take.

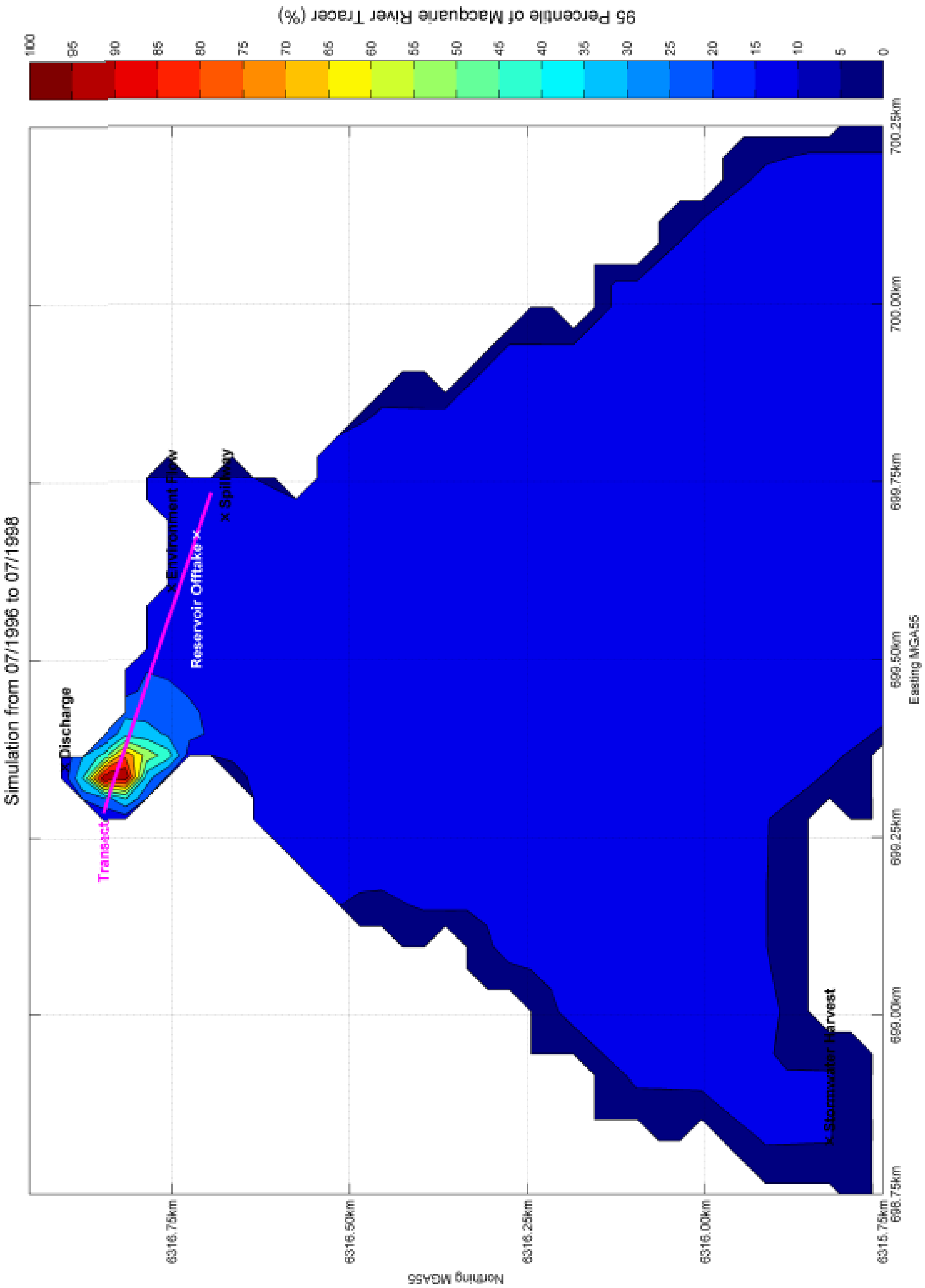


Figure 6-1. Proportion of Macquarie River Pumped Water within Reservoir

Water Quality Analysis within Reservoir

A simplified pollutant mass balance was undertaken based on the concentrations of each of the three input locations to the reservoir. This analysis is simplified in that there is no decay or water quality processes incorporated. For example, there is no die-off of E-coli modelled in this process. Instead, the average concentrations for each water quality parameter are applied to the conservative tracers (or representative concentration from each inflow point) to determine an overall concentration at various points within the reservoir.

The results of this tracer analysis have been applied to four key water quality parameters of interest:

- Bromide – due to the importance of this parameter in terms of the treatment process.
- Total Nitrogen & Total Phosporous – to determine the potential for algal blooms to form at certain areas in the reservoir
- E.Coli – based on likely human health impacts, both within the reservoir and the treatment process.

Table 6-3 shows the average concentration of the four parameters in the inflows used in the tracer analysis. It should be noted that the inflow water quality data was too sparse and irregular to use a time series of inflow concentrations. This data was then combined with the 95th percentile tracer percentage at the locations shown in **Figure 6-2.** The individual contributions from each source were combined using a weight based on the proportion of marker contaminant contributed to the total 95th percentile tracer percentage.

Table 6-3 Average of Concentration of Main Pollutants at Inflows

	Suma Park Catchment Inflow	**Macquarie River Drought Relief**	**Stormwater Harvest**
Bromide (mg/L)	0.07	0.09	0.02
Total Nitrogen (mg/L)	0.60	0.74	0.94
Total Phosphorus (mg/L)	0.05	0.04	0.05
E.Coli (CFU/L)	3000	650	120

Figure 6-2 Locations where concentrations are reported in Table 6.3.

Table 6-4 presents the 95th percentile concentration at the locations in **Figure 6-2** for each of the four parameters. The results generally compare well with that of the preliminary mass balance, indicating no major increases in concentration with Macquarie River pumping. The spatial variation in the 95th percentile concentration is also not significant across all parameters, except near the discharge location (see **Table 6-4** and Figures in **Appendix F**). Parameter concentrations near the discharge location tend to increase more than other locations in the reservoir (as would be expected).

Bromide is unlikely to impact on the environmental health of the reservoir, with the primary impact potentially on the treatment plant. Only a small increase is observed at the Reservoir Off-take, and as noted in **Section 8**, the treatment plant should be capable of withstanding these small increases in Bromide.

There are only small increases in concentrations in nutrients throughout the reservoir. However, as noted, there are complex processes of algal growth that affect nutrient concentrations that are not incorporated in this analysis. However, the analysis indicates that the nutrient concentrations would not be significantly different to the existing scenario, and therefore the risk of algal blooms is unlikely to be significantly higher.

The exception to this is near the discharge point from the pipeline. In the immediate vicinity of the discharge point, there is the potential for a localised increase in nutrient concentrations, particularly total nitrogen. This may result in a higher localised risk to algal blooms in this particular area. There are a few potential mitigation options to address this, including:

1. Incorporation of an inflow wetland, which would provide a polishing of the Macquarie River inflows prior to entering the Reservoir.
2. Provision of bubblers or circulation devices in this area to encourage more mixing.
3. Provision of a high flow and/ or turbidity based trigger limit for the Macquarie River flows, as per **Section 6.1.3**.
4. Operational controls. Undertake regular sampling of the reservoir, and use this to define operational practices that reduce the risk of algal blooms. This is likely to be the most practical for this project, particularly given that the modelling to date only provides an indication of an increase in risk of algal growth. It may also be used in combination with 3 above to identify, with greater sampling and information available of real time operation of the pipeline, on the impact to the Reservoir. Additionally, option 2 could be utilised should it be deemed necessary during operation of the pipeline.

The expected increases in e-coli concentrations are relatively minor, and therefore are not expected to represent a significant increase in risk to the reservoir. As noted above, it is expected that these concentrations are conservative as the exposure to UV light and other processes will result in lower concentrations of e-coli.

Table 6-4a 95% ile Results at various locations in the reservoir – Bromide (mg/L)

	Model without Macquarie River Inflow	Model with Macquarie River Inflow
Suma Park Catchment	0.07	0.08
Stormwater Harvest	0.07	0.08
Discharge	0.06	0.13
Reservoir	0.07	0.08
Reservoir Offtake	0.06	0.08

Table 6-2b 95% ile Results at various locations in the reservoir – Total Nitrogen (mg/L)

	Model without Macquarie River Inflow	Model with Macquarie River Inflow
Suma Park Catchment	0.65	0.70
Stormwater Harvest	1.06	0.98
Discharge	0.64	1.15
Reservoir	0.66	0.76
Reservoir Offtake	0.66	0.77

Table 6-2c 95% ile Results at various locations in the reservoir – Total Phosphorus (mg/L)

	Model without Macquarie River Inflow	Model with Macquarie River Inflow
Suma Park Catchment	0.05	0.06
Stormwater Harvest	0.07	0.07
Discharge	0.05	0.08
Reservoir	0.05	0.06
Reservoir Offtake	0.05	0.06

Table 6-2d 95% ile Results at various locations in the reservoir – E.Coli (CFU/L)

	Model without Macquarie River Inflow	Model with Macquarie River Inflow
Suma Park Catchment	3010	3050
Stormwater Harvest	2740	2770
Discharge	2690	3120
Reservoir	2700	2790
Reservoir Offtake	2690	2790

6.1.6 Summary and Conclusions

The introduction of pumped water from the Macquarie River into Suma Park Reservoir has the potential to impact on the water quality within the reservoir. While it has been noted in **Section 8** that there would be minimal impacts on Icely Treatment Plant, there is also the potential for impacts on the environment of the Reservoir itself.

A preliminary analysis of impacts on reservoir water quality was undertaken by pollutant mass balance modelling with key parameters that were identified in a comparison of Macquarie River and Suma Park Reservoir water quality data. This is a simple analysis assuming conservative species and perfect mixing in the reservoir, to identify potentially problematic pollutants for the health of the reservoir. The analysis was undertaken comparing the existing scenario with a pumping scenario. The pumping scenario adopted incorporated a pump rate of 12 ML/day into the reservoir when storage drops below 90% and river flow is greater than 34 ML/day.

The outcome of this modelling indicates that there are unlikely to be significant changes in the water quality within the reservoir overall. While some parameters are worse in the river compared with the reservoir, the volume of water being pumped in comparison to the reservoir volume is insufficient to result in a significant impact. However, there may be localised changes in water quality in the vicinity of the discharge point from the pipeline. The level of this impact will be dependent on the level of mixing at the discharge point. 3D modelling has been undertaken to address the likely mixing of the pipeline input with the reservoir, and to identify any control measures if required. This has been undertaken for four key parameters: Bromide, TN, TP and E.Coli. The results of this modelling are generally consistent with the preliminary mass balance modelling, indicating that concentrations do not increase significantly when river pumping occurs.

The 3D modelling has indicated however that there are likely to be some localised increases in concentration of nutrients in the vicinity of the discharge point, which may result in an increased risk of algal blooms in this area. A number of options for mitigating these risks have been identified in **Section 6.1.5.** The recommended approach is to mitigate this risk through operational controls. This would involve monitoring of the reservoir for algal concentrations. Given the high level of the analysis undertaken in this assessment, and the limited data available, this is likely to be the most pragmatic approach. This would require monitoring of the Reservoir in the vicinity of the discharge point, and identifying risk periods and trigger limits from the Reservoir where algal concentrations may become acceptable as a result of pumping.

It is noted that the reservoir is not used for recreational purposes, so the primary risk is to the ecology of the reservoir. Given the localised area that is impacted, this operational approach is considered reasonable.

While the water quality sampling undertaken to date provides a number of data points, there are some limitations with some parameters only having a few data points. Furthermore, all samples were taken for river flows that exceed 100ML/day, which is above the trigger level. It would be recommended that additional sampling be undertaken for key parameters that are identified as a potential issue in the report to ensure that the expected relationships identified in the report remain consistent.

During operation of the pipeline, it is recommended that some real time measurements be undertaken on some key parameters, such as turbidity and electronic conductivity, to identify a deterioration of water quality in the River. If this is to occur, then a decision can be made to shut off the pipeline if required. The relationships with flow, turbidity and electronic conductivity provided in **Section 6.1.3** can provide a level of guidance in the likely change in key water quality parameters.

There is potential deterioration of water quality in the pipe if pumping ceases for a long period of time. It is recommended that in-line dissolved oxygen measurements be provided. This is particularly important if the BOD within the river water is high, as it may result in low dissolved oxygen water being present in the pipe.

Assessment of the Impact on Reservoir Water Quality

The impact of the project on Reservoir water quality has been assessed according to the *Neutral or Beneficial Effect on Water Quality Assessment Guideline* (Sydney Catchment Authority, 2011). Specifically, Section 3.1 of the guideline specifies that a neutral or beneficial effect on water quality is satisfied if the development:

a) has no identifiable potential impact on water quality, or
b) will contain any water quality impact on the development site and prevent it from reaching any watercourse, waterbody or drainage depression on site, or
c) will transfer any water quality impact outside the site where it is treated and disposed of to standards approved by the consent authority.

According to the above criteria, the introduction of pumped water from the Macquarie River to Suma Park Reservoir is considered to have a neutral effect on Reservoir water quality. This is based on the following:

- No identifiable impact on drinking water quality, due to minimal impacts on the Icely Treatment Plant (as noted in **Section 8**).
- Potential impacts on reservoir water quality have been identified, mainly with regards to the ecological health of the reservoir. However, monitoring measures have been identified to help contain and minimise the risk of algal blooms and deterioration of water quality (as discussed above).

6.1.7 Qualifications

- Sample sizes for most of the parameters considered are between 9 and 15. This gives rise to the potential for bias in the sample average and medians, upon which much of the analysis is based. Furthermore, the small sample sizes may not capture extreme values of parameter concentrations, which can be important in determining whether monitoring needs to be carried out.
- Temporal variability in the data may not be captured for the sampling period.

  Modelled river flow was used instead of gauge flow in determining relationships between flow and concentration as the gauge was located upstream of the water quality sampling site.

Table 6-5. Summary of water quality relationships

Parameter	Relationship	Discussion	Implications
EC	Decreases with Flow	Both TDS, EC, and Bromide have a similar relationship with flow. This suggests that the salt concentrations in the River increase with decreasing flow.	Higher salt concentrations may have a longer term impact on the Reservoir water quality and as a result also the treatment plant. Water balance modelling suggests that is unlikely to be a significant impact based on sampling undertaken.
TDS	Decreases with Flow Correlated with EC	As with EC	As with EC
SS	Generally increases with flow	Both Turbidity and SS generally increase with flow, but there is a relatively loose relationship.	Concentrations are not significantly greater than reservoir for majority of time. More likely to be greater impacts from related parameters.
Bromide	Decreases with flow Correlated with EC	Similar relationship to EC.	Limited environmental issues. Potential implications for the treatment plant, particularly in regards to ozonation. Is discussed in detail in Section 8.
Ba	Decreases with flow		Minimal environmental impacts. Not identified as significant for treatment plant in Section 8.
Aluminium	Increases with flow	Both Fe and Al have a similar relationship with flow.	Given the level of the pH, there is limited environmental implications.
Manganese	No relationship with flow		Not identified as an issue for the treatment plant in Section 8. Minimal impacts on environment.
Fe	Increases with flow	As with Al	Limited environmental implications. No identified impact on treatment plant in Section 8.
Nitrate, TKN, TN etc	Generally increases with flow Increases with turbidity	Relationship with flow suggests a general increase. There is also a relationship with turbidity, which may allow for a secondary trigger based on turbidity levels. One of the key challenges with the nutrients is that they are dependent on a number of processes in the reservoir. Therefore, while the concentrations may be lower than those in the Reservoir, the additional input loads from the pipeline may influence algal growth in the reservoir	Environmental implications for algal growth. Water balance modelling suggests that water quality in reservoir will not deteriorate over existing conditions, based on available sample data. No identified impact on treatment plant
TP	Generally increases with flow	The relationship with flow is generally increasing, but there is not a clear relationship. Similar issues to TN.	As above. TP values are expected to decrease in the reservoir based on water balance modelling.
TOC	Increases with flow.		Not identified as an issue for the treatment plant in Section 8. Minimal environmental implications.

Parameter	Relationship	Discussion	Implications
BOD	No clear relationship	There is no clear relationship with flow, EC or Turbidity.	BOD has the potential to affect water that may be stored within the pipe for longer periods of time. Therefore, likely to require a DO in-line measurement together with the ability to flush the line.
Somatic Coliphages	No clear relationship with flow. Increases with turbidity	Turbidity is likely to be the best indicator trigger for Somatic Coliphages.	No likely impact on the treatment plant, as discussed in Section 8.
Clostidium Perfringens	No clear relationship	No clear relationship with EC, Turbidity or flow.	No likely impact on the treatment plant, as discussed in Section 8.

6.2 Water Quality in Creeks

Water quality in the creeks may be impacted both during construction and when the pipeline becomes operational. The impacts during construction are primarily related to erosion and sediment control, and this is discussed further in **Section 5.3** with monitoring measures identified in **Section 6.3**.

During the operation of the pipeline, it is understood that scouring of the pipe may be required after prolonged periods of the pumps not being in operation. This may occur if the Macquarie River flows are below their trigger levels or the Reservoir has sufficient water. In such a situation the water in the pipeline will have deteriorated, such as the dissolved oxygen. It is understood that scour valves will be used to allow for the pipe to be scoured or “flushed.”

6.2.1 Description of Scour Valves

Scour valves would be located at low points of the pipeline to facilitate maintenance and emergency drainage of the pipeline. Scour valves would be buried and fitted with a spindle and valve box flush with the existing ground level. The valves would discharge to a nominal 750 mm diameter scour pit. Scour pits would be approximately 1 to 2 m deep and finished flush with the existing ground level. Approximately 60 scour valves would be required.

6.2.2 Operation of Scour Valves and Dewatering

Operation (opening) of the scour valves would allow dewatering of the pipeline for emergency repairs and during commissioning (if required). Dewatering would involve release of water to scour pits via the scour valves. Scour water would be managed in accordance with the scour water management plan, which would form part of the project operation environmental management plan. Scour water would either be discharged from the pits to the closest watercourse (subject to meeting the water quality requirements and at controlled velocities as defined by the scour water management plan) or transferred from the pits via a suction tanker truck to the stormwater holding pond or Council’s sewage treatment plant.

Section and isolation valves are included in the design of the project to minimise the potential for accidental discharge of significant volumes of water to the environment in the event of any incidents such as pipe failure. In the unusual event that pipeline repairs require dewatering of the pipeline, water would be released in a controlled manner through the scour pits and via erosion and sediment control features provided in the project design.

As the water released would be raw water from the Macquarie River and would only be released to the environment in accordance with the scour water management plan (which would include minimum water quality standards) it is unlikely to result in impacts to the environment.

Approximately once every 10 years the pipeline would be cleaned via a process called ‘pigging’. Water from this cleaning would contain material scoured from the wall of the pipe and would be of poorer quality than the river water being transferred. This water would be gradually discharged to Council’s sewage treatment plant, where it would be treated prior to discharge.

6.2.3 Scour Water Management Plan Outline

The preferred approach to the management of scour water would be to discharge water to the natural environment if relevant water quality standards are met. Alternatively, water would be collected from the scour pits by tanker trucks and transferred to the stormwater holding pond or Council's sewage treatment plant.

The water quality in the pipeline will be a function of the water quality from the Macquarie River when the water was pumped together with the period of time that the water has remained dormant in the pipeline. If scour water is to be released into the creek systems, it may be necessary to provide treatment measures in the vicinity of the scour valves to improve the water quality prior to its release. For example, it may be necessary to have some holding ponds/ wetlands together with a riffle zone prior to the creek to enhance dissolved oxygen and lower any nutrients.

If discharging scour water to the creek is proposed, then the following assessments are recommended:

- Water quality sampling at the creeks where scouring is proposed, to determine a baseline for the assessment;
- Analysis of likely frequency of scouring of the pipeline and the volume of water to be discharged at each of the valves;
- Analysis of the likely water quality within the pipeline prior to scouring;
- Analysis of the scoured water and determine whether treatment is required prior to discharge into the creek systems.

It is understood that a scour water management plan would be developed to manage the release of scour water during operation. It would be developed in consultation with the Central West Catchment Management Authority and the NSW Office of Water. The plan would include identified sites for the release of scour water; details regarding scheduling and monitoring; water quality targets; and alternatives for the management of scour water if it cannot be released to the designated sites.

The plan would form part of an operation environmental management plan for the project. The plan would allow for:

- notification of property owners by appropriate means (except in contingency circumstances);
- agreed water quality parameters and release criteria (such as controlled velocities to reduce energy);
- procedures for water quality sampling and analysis prior to release;
- water release methodology and procedures;
- water transfer procedures if release criteria cannot be met;
- inspection and repair (if necessary) of erosion and sediment controls.

6.3 Water Quality During Construction

In accordance with *Managing Urban Stormwater Soils and Construction Volume 2A Installation of Services,* where services need to be placed across a creek, stream or waterway, measures need to be undertaken to:

- Divert the water flow while the service is being installed,
- Protect the waterway from erosion and sediment damage, and
- Maintain flow to avoid upstream flooding.

To mitigate the impacts of construction works on water quality in the works area, various preliminary erosion and sediment control measures and flow diversion measures have been recommended for each creek crossing and the off-take (see **Section 5.3**), giving consideration to maintaining flows to avoid upstream flooding. These should be updated and refined as the design is progressed.

A preliminary surface water quality monitoring framework has also been developed for the construction phase, to monitor any potential impacts on the watercourses and the effectiveness of the erosion and sediment control and flow diversion measures in place. This water quality monitoring framework is provided in **Table 6-7**. As with the erosion and sediment control measures, this should be refined and updated as the design progresses.

A key component of the monitoring framework is the monitoring checklist, which is to be completed on-site at each of the creek crossings and the off-take at the frequencies specified in the monitoring framework in **Table 6-7**.

A proposed monitoring checklist to take out on-site is provided in **Table 6-8**. The checklist contains a range of visual criteria proposed to identify any potential impacts on water quality due to construction works. If one of the visual criteria is triggered, then further action may be required to rectify or manage the issue and the 'Incident Response Procedure' identified in the monitoring framework in **Table 6-7** should be followed.

Sites where regular periodic water quality sampling has been proposed during construction include the Macquarie River at the off-take site, the Suma Reservoir and crossings across the larger creeks as identified in the geomorphological and hydrological assessment. Similar water quality monitoring may be required as part of the incident response procedure at creek crossing sites if impacts on water quality are occurring, particularly during trenching activities across a watercourse and when equipment is operating directly on the banks of the watercourse. Due to the lack of water quality data at individual stream crossings to provide a base case, water quality sampling should be carried out upstream of the work zone (approximately 20 metres where feasible) to describe existing water quality. This would then be compared to water quality downstream of the work zone (approximately 20 metres where feasible) to determine the impact of construction activities. This should be undertaken for the offtake, Suma Reservoir and the creek crossings identified in Table 6-6 (see Figure 1.1). See the monitoring framework in **Table 6-7** for water quality sampling details.

It is recommended that any contractors undertaking the work for the project are aware of *Managing Urban Stormwater Soils and Construction Volume 2A Installation of Services* and are familiar with the requirements.

Table 6-6. Creeks for Water Quality Sampling

Crossing #	Chainage (m)	Name
1	34,800	Summer Hill Creek
2	34,000	Summer Hill Creek
3	32,630	-
4	29,600	Summer Hill Creek
19	27,085	-
21	24,500	Cow Creek
5	21,870	Summer Hill Creek
6	20,730	Kittys Creek
7	17,550	-
12	13,850	Oaky Creek
25	13,500	Oaky Creek
14	12,126	-
30	4,358	-
Off-take	0	Macquarie River

Table 6-7. Surface water quality monitoring framework

Monitoring Activities	Monitoring Frequency	Incident Response Procedure
Dry Weather Monitoring		
Visual observations in the vicinity of each creek crossing and the off-take for: ▪ Integrity of erosion and sediment controls (gravel filters or hay bales), ▪ Integrity of flow diversion measures (diversion walls or coffer dams or other measures proposed), ▪ Stream water clarity and general water appearance, ▪ Flow conditions, and ▪ Bank condition and stability. Complete the checklist provided in **Table 6-8**.	Twice daily inspections when undertaking works in the vicinity of the creek crossing/off-take; prior to the commencement of works for the day and once works have been completed for the day.	If a breach / incident is observed: ▪ Stop work and notify the site superintendent immediately, ▪ Implement temporary erosion and sediment control measures immediately, such as sandbags or in-stream silt curtains, if required, ▪ Undertake in-situ water quality monitoring and collect laboratory water samples (if required) to confirm or determine the extent / nature of the breach, ▪ Reinforce or reinstate the erosion and sediment control flow diversion measures as soon as possible, and ▪ Assess whether additional erosion and sediment control and/or flow diversion measures are required. If so, determine the additional measures and install them prior to re-commencing works in the vicinity of the incident. If an incident occurs real time measurements of the following should be made in-situ, as a minimum, to confirm or determine the extent / nature of the breach: ▪ Turbidity, ▪ pH, and ▪ DO. Laboratory sampling required should be determined on a case by case basis. For example, if an oil spill occurred (i.e. during refuelling of machinery) or oil is visible on the water surface laboratory samples should be collected for oil and grease and Total Petroleum Hydrocarbons (TPH).
Water quality sampling at the locations identified in **Table 6.6** (see **Figure 1.1**), for the following: In-situ using a water probe: ▪ Turbidity, ▪ pH, and ▪ Dissolved Oxygen (DO). Water samples for laboratory analysis: ▪ Total Suspended Solids (TSS), ▪ Total Nitrogen (TN), and ▪ Total Phosphorous (TP). Note that laboratory analysis of samples generally requires a seven day turnaround to obtain results.	Twice daily measurements using an in-situ water probe for turbidity, pH and DO when undertaking works that impact upon the creek crossings, off-take and Suma Reservoir; prior to the commencement of works for the day and once works have been completed for the day. Weekly measurements of TSS, TN and TP should be undertaken by collecting water laboratory samples when undertaking works that impact upon the creek crossings, off-take and Suma Reservoir, noting the turnaround time required for sample analysis. Sampling only required while works are being undertaken within the vicinity of the creek crossings.	

Monitoring Activities	Monitoring Frequency	Incident Response Procedure
Wet Weather Monitoring		
Additional visual observations in the vicinity of each creek crossing and the off-take (Macquarie River) should be undertaken. Complete the checklist provided in **Table 6-8**.	Inspections should be undertaken as soon as possible of creek crossings/off-take once >10mm of rainfall in 24 hours has occurred (Not required where works have either not commenced or have been completed)	The same as for dry weather.

Table 6-8. Surface water quality monitoring checklist

Surface Water Quality Monitoring Checklist		
Creek Crossing Site:		
Date / Time:		
Weather Conditions:		
Name of Visual Observer:		
Visual Criteria (Circle Yes or No) Note: 'No' means a Visual Criteria has been triggered and further action may be required		**Descriptions / Comments / Notes**
Are the erosion and sediment control measures (i.e. gravel filter or hay bale) intact and functioning as intended?	Yes / No	
Are the flow control measures (i.e. diversion wall or coffer dam) intact and functioning as intended?	Yes / No	
Is the water upstream of the control measures clear? If not describe how silty and/or turbid the water is.	Yes / No	
Is the water downstream of the control measures clear? If not describe how silty and/or turbid the water is.	Yes / No	
Is the watercourse generally in good / normal condition? If not and there is anything unusual in and/or on the water (i.e. oil slick, dead fish, frothy bubbles, strong odours present, etc, then note the unusual occurrence/s.	Yes / No	

Surface Water Quality Monitoring Checklist		
Does the water flow appear normal? Describe flow rates, width, depth of channel, etc.	Yes / No	
Do the creek banks appear stable (i.e. no undercutting, collapsing or slumping noticeable), particularly in areas where equipment is operating on the creek banks?	Yes / No	
Does the vegetation along the banks appear healthy and stable, particularly in areas where equipment is operating on the creek banks?	Yes / No	
Incident Response (Circle Yes or No)		**Actions Required to Rectify Incident**
Was a breach or incident affecting water quality identified? If yes, attach the incident report to this checklist.	Yes / No	

7 GROUNDWATER

A broad-level review of potential impacts to groundwater resources over the pipeline route based on a field reconnaissance and review of publically available data was undertaken by Pells Consulting and is detailed in **Appendix C**.

For the pipeline route, they conclude that pipeline construction will have "minor to non existent" impacts on groundwater resources, specifically, "negligible" impacts on groundwater users. Furthermore, they recommend that groundwater monitoring along the route of the pipeline is "not appropriate" and that no special mitigation measures are required to protect groundwater resources adjacent to the pipeline route.

For the Macquarie River, extraction of surface water at the intake will impact slightly on stage in the river at locations downstream of the intake. The project will not impact on surface-groundwater exchanges upstream of the intake as it will not reduce surface water discharges at locations upstream of the intake.

This decrease in stage will induce a decrease in the water table level in aquifers that are adjacent to the river. The change in the water table will be less than the change in river stage, and will diminish with distance.

It can be shown that the maximum change in river stage due to the abstractions will occur for abstractions taken during the lowest permissible river discharge. Specifically, the greatest change in stage in the Macquarie River will occur when abstractions of 12 ML a day are taken when river flows are at 34 ML/day.

The maximum change in river stage due to abstractions of 12 ML/day is in the order of 30 to 50 mm. At other times (ie during higher flows) the change in stage would be less, and the changes would diminish with distance downstream until they become negligible at Lake Burrendong.

This small change in river stage would theoretically induce a small change in the groundwater levels adjacent to the river. The maximum magnitude of change in groundwater would be close to 30 to 50 mm adjacent to the river, but would diminish with distance from the river.

Based on the nature of aquifers, the nature of the project and the designation of low to low-moderate vulnerability, it is believed that groundwater monitoring along the route of the pipeline is not appropriate to support this project application.

Groundwater monitoring adjacent to the Macquarie River is not believed to be appropriate. Indicative Maximum Change in Groundwater Levels Adjacent to Macquarie River are included in the table below:

Distance from River	20 m	50 m	100 m
Change in Groundwater Level	10 mm	2 mm	< 0.1 mm

No special mitigation measures are considered appropriate or required for protection of groundwater resources adjacent to the pipeline route.

The only mitigation strategy that is recommended is, in the case of a major spill or pipeline breakage, a qualified hydrogeologist should be engaged to review the event, and to determine the nature of groundwater related responses that are required, if any.

8 IMPACTS ON WATER TREATMENT PLANT

An analysis was undertaken on the likely impact of the proposed pipeline on the water treatment plant in regards to water quality. This report was prepared by MJM Environmental and is detailed in **Appendix D**. A summary of the key outcomes is provided below.

The discharge of flow from the pipeline to existing water supply infrastructure would introduce additional water from a new source. This has the potential to affect the operation of existing water supply infrastructure, particularly if the quality of the water is low. An assessment has therefore been undertaken on the likely impact of pumping water from the Macquarie River on the Icely Treatment Plant. Note that an assessment has also been undertaken on the impact of the pipeline on the water quality within the reservoir itself, and this is described in Section 6.3.5.

The following comparisons are made of the water quality characteristics of the new raw water source (Macquarie River) against the existing raw water source (Suma Park Dam):

Macquarie River generally has poorer quality raw water compared to Suma Park Dam raw water:

- Turbidity, suspended solids, true colour and total dissolved solids (TDS) levels are higher for Macquarie River than Suma Park Dam
- Total organic carbon (TOC) levels are relatively similar between the two raw water sources
- Iron (total) is higher for Macquarie River than Suma Park Dam
- Suma Park Dam raw water alkalinity and hardness is lower than Macquarie River

Based on a review of the Suma Park Dam and Macquarie River raw water quality and potential blending scenarios, and a review of the Icely Road WTP process, it is recommended that:

- Macquarie River generally has poorer quality raw water compared to Suma Park Dam raw water.
- Icely Road WTP is capable of treating all raw water quality parameters for the new water supply assuming complete mixing and including when entirely sourced from Macquarie River.
- OCC undertake additional testing to verify the water quality parameters in Macquarie River including true colour and soluble iron.
- Complete bench-scale jar testing to verify true colour removal for the plant if true colour levels in Macquarie River are found to be high during typical raw water conditions.
- The current treatment process achieves a minimum log removal of 3 for Cryptosporidium, 6.5 for Giardia, and 10 for viruses.
- The major parameter of concern for the new raw water supply is bromide. OCC should develop and implement a bromide process optimisation strategy for the plant.

Bromide is the major parameter of concern for OCC and should be monitored closely if Macquarie River water is pumped to Suma Park Dam. While there is no ADWG limit for bromide, the chemical is oxidised by ozone to form bromate. Bromate is toxic to humans and is a suspected carcinogen. It is recommended that OCC undertake monthly bromide monitoring in Macquarie River and develop a bromide process optimisation strategy for operation should elevated bromide levels above 0.1 mg/L be experienced.

9 PIPELINE CONSTRUCTION AND OPERATION

9.1 Proposed Pipeline Construction

The design of the pipeline is currently being refined by MWH. For the purposes of this report, the following key assumptions in regards to the design have been made in consultation with Council and GHD:

- The off-take would be located at the site detailed in **Section 3**;
- The pipeline would be constructed nearly entirely underground, through a combination of trenching and tunnelling. For the purposes of the creek crossing assessments, we have assumed that trenching would be utilised as this is likely to be the worst case in terms of disturbance;
- Scour valves would be limited as much as possible along the pipeline. Where possible, scouring of the pipe would be undertaken without the need to discharge to the local creeks.

10 CONCLUSIONS

The following provides a brief overview of the findings of the various components of this report, together with the key recommendations from each section.

10.1 Hydrological Modelling

Hydrological modelling has been undertaken for the major creek crossings along the pipeline route, defining peak flows for the 2 year ARI, 5 year ARI, 20 year ARI & 100 year ARI design events.

This information can subsequently be utilised to assist with the design process for the pipeline. As the pipeline is proposed to be underground, there should be a limited impact on the hydrology in the study area because the proposed works do not alter the cross section of the creek.

Insufficient survey data was available at the time of this report to define indicative flood levels at each of the creek crossings. Flood levels can be determined when this data becomes available utilising the flows determined in these assessments

Key Recommendations

- In the event that lengths of the pipeline are to be constructed above ground in the vicinity of the creek crossings, then a flood impact assessment should be undertaken to ensure no adverse impacts in the events up to the 100 year ARI event. Furthermore, the expected loadings from flood flows and debris would need to be considered.
- Similarly, any above ground infrastructure should be located above the 100 year ARI event to minimise impacts of flood behaviour.
- To minimise potential damage to pumping infrastructure, pumps would be placed above the 100 year ARI flood level plus a freeboard of 500mm.

10.2 Geomorphology

Preliminary geomorphology assessment was undertaken for the stream crossings of the pipeline route was undertaken using a rapid geomorphology assessment proforma (Simon et al 2007) and the Strahler method (Strahler 1957). The streams assessed were generally stable where the bed and banks are controlled by bedrock. Some streams were classified as unstable or sensitive based on the bed and bank material being of soil and exposed to stream flow. Impacts of the pipeline are generally limited to construction where disturbance of the stream would occur by trenching the pipeline. The impacts are expected to be more significant for the streams that are classified as sensitive or unstable.

Assessment of the geomorphology of the Macquarie River offtake and the Suma Reservoir discharge has also been undertaken. It was found that both locations are suitable for the works proposed and mitigation measures are proposed for the likely impacts as a result of construction and operation of the pipeline. The following key recommendations summarise the mitigation measures identified.

Key Recommendations

- Typical sediment and erosion control measures have been proposed in **Appendix A** for a range of stream types and conditions. Selection of the most appropriate measure is based on the guidance provided in **Table 5.5.** The measures and their application is subject to further refinement once more detail in the design of the pipeline is known.
- Rehabilitation of the disturbed surface at the stream crossings is to be undertaken in the form of either local rock/concrete encasement for creeks of bedrock or topsoil and revegetation for creek of soil. Typical details of these methods is provided in drawing W4916-2 (**Appendix A).**
- The Macquarie River Offtake would not pose significant impact to the river geomorphology, however scour protection is proposed around the offtake structure to resist erosion. The preliminary calculations and layout of the scour protection is based on the results of the HEC RAS model provided (Geolyse 2012). This should be updated with a more detailed hydrodynamic model following further detail in the design.
- The discharge to Suma Reservoir should be lined with scour protection and laid at a slope of no more than 1 vertical to 6 horizontal. The width and configuration of the rock lining shall be determined once design flow rates from the discharge are determined during detailed design.

10.3 Water Quality

10.3.1 Water Quality in Creeks

The creek crossings along the length of pipeline may be impacted both during construction and also during the operation of the pipeline. The following provides an overview of the analysis in this report and the key recommendations.

During Operation

Water quality in the creeks may be impacted both during construction and when the pipeline becomes operational. During the operation of the pipeline, it is understood that scouring of the pipe may be required after prolonged periods of the pumps not being in operation. This may occur if the Macquarie River flows are below their trigger levels or the Reservoir has sufficient water. In such a situation the water in the pipeline will have deteriorated, such as the dissolved oxygen.

Key Recommendations

If scour valves and scouring to the creek is proposed, then the following assessments are recommended:

- Water quality sampling at the creeks where scouring is proposed, to determine a baseline for the assessment;
- Analysis of likely frequency of scouring of the pipeline and the volume of water to be discharged at each of the valves;

- Analysis of the likely water quality within the pipeline prior to scouring;
- Analysis of the scoured water and determine whether treatment is required prior to discharge into the creek systems.

During Construction

The impacts during construction are primarily related to erosion and sediment control, To mitigate the impacts of construction works on water quality in the works area, various preliminary erosion and sediment control measures and flow diversion measures have been recommended for each creek crossing and the off-take depending on the conditions at each site (refer **Section 5**). A surface water monitoring frameworks has also been drafted to assist with implementation of sediment and erosion control (refer **Section 6**).

Key Recommendations

- Erosion and sediment control be implemented as a part of the design. Examples have been provided in Appendix A and discussed in Section 5.
- A surface water monitoring framework be implemented for the works during construction. A draft framework has been provided in Section 6.
- It is recommended that any contractors undertaking the work for the project are aware of *Managing Urban Stormwater Soils and Construction Volume 2A Installation of Services* and are familiar with the requirements.

10.3.2 Water Quality in Suma Park Reservoir

The introduction of pumped water from the Macquarie River into Suma Park Reservoir has the potential to impact on the water quality within the reservoir. While it is noted that the analysis has identified minimal impacts on the treatment plant, there is also the potential for impacts on the environment of the Reservoir itself.

A preliminary analysis of impacts on reservoir water quality was undertaken by pollutant mass balance modelling with key parameters that were identified in a comparison of Macquarie River and Suma Park Reservoir water quality data.

The outcome of this modelling indicates that there are unlikely to be significant changes in the water quality within the reservoir overall. While some parameters are worse in the river compared with the reservoir, the volume of water being pumped in comparison to the reservoir volume is insufficient to result in a significant impact. However, there may be localised changes in water quality in the vicinity of the discharge point from the pipeline. The level of this impact will be dependent on the level of mixing at the discharge point. 3D modelling is currently being undertaken to address the likely mixing of the pipeline input with the reservoir, and to identify any control measures if required.

While the water quality sampling undertaken to date provides a number of data points, there are some limitations with some parameters only having one or two sample points which limits the ability to compare the river and reservoir water quality. Furthermore, all samples were taken for river flows that exceed 100ML/day, which is above the trigger level.

Key Recommendations

- It would be recommended that additional sampling be undertaken for key parameters that are identified as a potential issue in the report to ensure that the expected relationships identified in the report remain consistent.
- During operation of the pipeline, it is recommended that some real time measurements be undertaken on some key parameters, such as turbidity and electronic conductivity, to identify a deterioration of water quality in the River. If this is to occur, then a decision can be made to shut off the pipeline if required.
- It is recommended that operational controls be implemented to monitor algal concentrations in the vicinity of the Discharge point to the reservoir. This can be used to inform high risk periods for algal growth in this area and whether the pumping from the Macquarie River has an adverse impact on the overall algal growth within the Reservoir. Some suggestions on likely mitigation measures to reduce algal growth, should this become a problem, are suggested in **Section 6.1.5**

10.4 Groundwater

A broad-level review of potential impacts to groundwater resources over the pipeline route based on a field reconnaissance and review of publically available data was undertaken by Pells Consulting and is detailed in **Appendix C**.

For the pipeline route, they conclude that pipeline construction will have “minor to non existent” impacts on groundwater resources, specifically, “negligible” impacts on groundwater users. Furthermore, they recommend that groundwater monitoring along the route of the pipeline is “not appropriate” and that no special mitigation measures are required to protect groundwater resources adjacent to the pipeline route.

For the Macquarie River, extraction of surface water at the intake will impact slightly on stage in the river at locations downstream of the intake. The project will not impact on surface-groundwater exchanges upstream of the intake as it will not reduce surface water discharges at locations upstream of the intake.

The maximum change in river stage due to abstractions of 12 ML/day is in the order of 30 to 50 mm. At other times (ie during higher flows) the change in stage would be less, and the changes would diminish with distance downstream until they become negligible at Lake Burrendong.

This small change in river stage would theoretically induce a small change in the groundwater levels adjacent to the river. The maximum magnitude of change in groundwater would be close to 30 to 50 mm adjacent to the river, but would diminish with distance from the river.

Groundwater monitoring adjacent to the Macquarie River is not believed to be appropriate. Indicative Maximum Change in Groundwater Levels Adjacent to Macquarie River are included in the table below:

Distance from River	20 m	50 m	100 m
Change in Groundwater Level	10 mm	2 mm	< 0.1 mm

Key Recommendations

- No special mitigation measures are considered appropriate or required for protection of groundwater resources adjacent to the pipeline route.
- The only mitigation strategy that is recommended is, in the case of a major spill or pipeline breakage, a qualified hydrogeologist should be engaged to review the event, and to determine the nature of groundwater related responses that are required, if any.

10.5 Impacts on Treatment Plant

An analysis was undertaken on the likely impact of the proposed pipeline on the water treatment plant in regards to water quality. This report was prepared by MJM Environmental and is detailed in **Appendix D**. A summary of the key outcomes is provided below.

The discharge of flow from the pipeline to existing water supply infrastructure would introduce additional water from a new source. This has the potential to affect the operation of existing water supply infrastructure, particularly if the quality of the water is low. An assessment has therefore been undertaken on the likely impact of pumping water from the Macquarie River on the Icely Treatment Plant.

Based on a review of the Suma Park Dam and Macquarie River raw water quality and potential blending scenarios, and a review of the Icely Road WTP process, it is recommended that:

Key Recommendations

- Icely Road WTP is capable of treating all raw water quality parameters for the new water supply assuming complete mixing and including when entirely sourced from Macquarie River.
- OCC undertake additional testing to verify the water quality parameters in Macquarie River including true colour and soluble iron.
- Complete bench-scale jar testing to verify true colour removal for the plant if true colour levels in Macquarie River are found to be high during typical raw water conditions.
- The current treatment process achieves a minimum log removal of 3 for Cryptosporidium, 6.5 for Giardia, and 10 for viruses.
- The major parameter of concern for the new raw water supply is bromide. OCC should develop and implement a bromide process optimisation strategy for the plant.

Bromide is the major parameter of concern for OCC and should be monitored closely if Macquarie River water is pumped to Suma Park Dam. While there is no ADWG limit for bromide, the chemical is oxidised by ozone to form bromate. Bromate is toxic to humans and is a suspected carcinogen. It is recommended that OCC undertake monthly bromide monitoring in Macquarie River and develop a bromide process optimisation strategy for operation should elevated bromide levels above 0.1 mg/L be experienced.

11 REFERENCES

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Appendix A

Example Erosion & Sediment Control

Appendix B

Water Quality Analysis Figures

Appendix C

Pells Consulting Groundwater Report

Appendix D

MJM Environmental Report

Appendix E

Stream Inspection Documents

Appendix F

3D Reservoir Modelling Report